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Service Extensions to Suburban Areas

By *S. T. Anderson, M. B. Cunningham, C. M. McCord, H. B. Miles, W. C. Morse, Paul Weir and W. C. Wills*

A panel discussion presented on May 5, 1948, at the Annual Conference, Atlantic City, N.J.

S. T. Anderson

Gen. Supt., City Water, Light and Power Dept., Springfield, Ill.

SPRINGFIELD, Ill., has four distinct methods for extending water mains: (1) the special assessment plan, (2) the certificate plan, (3) the new customer plan and (4) the contract plan.

The special assessment plan is particularly adapted to new and thinly settled additions, and the mode of procedure is fixed by the Local Improvements Act. On the presentation of a petition signed by the owners of one-half of the frontage, the Board of Local Improvements must immediately cause to be prepared an estimate of the cost and must call a public hearing, at which any objections may be heard and considered by the City Council.

If it is decided that the improvement should be made, the City Council will then pass the required ordinance and the Superintendent of Special Assessments will prepare the roll or list of property benefited by the improvement, designate the estimated amount of the assessment against each lot or parcel of land and file this information with the county court. After the public hearing in the county court, the Board of Local Improvements will advertise for bids and make the necessary contract. The assessment is payable in cash immediately or in not more than three yearly installments, as may be desired by the property owners and fixed by the Board of Local Improvements. If less than one-half of the frontage owners petition for a water main, the council may proceed to lay the main or not, at its discretion.

The certificate plan provides a method by which one or more interested persons may secure the extension of a main at their own expense, paying the amount of the cost of the proposed extension to the water department. The Collector of Water Rates will issue a noninterest-bearing certificate for the amount paid which will provide for the refund of the cost of laying 35 ft. of main for each new customer, as fixed by the city ordinance.

The new customer plan, which is especially adapted to the old settled parts

of the city, furnishes the means for securing a water main extension to an adjacent block. Under this plan, the water department will, free of charge, extend the street main 35 ft. for each property owner who applies and contracts to use the water, making an advance payment of the amount of the installation cost. For the average block of 320 ft., nine customers are sufficient. For shorter or longer blocks, the required number of customers may be ascertained by dividing the number of feet necessary for the main extension by 35, the number of feet of main that will be laid by the department for each new customer, as fixed by city ordinance.

The contract plan is used for the extension of mains outside of the city limits. The prospective customer may be either an agent for a new subdivision or a group of individuals in a built-up area. At the request of the extension customer, the department engineer prepares a drawing of the proposed extension, together with a cost estimate. If the customer decides to have a new main installed, he deposits with the water department the amount of the estimate. A special contract is then drawn up between the customer and the city and is submitted to the City Council with the proper ordinances for approval. After the contract has been approved and the signatures authorized, the city proceeds with the installation. The contract form employed is shown in the appendix to this discussion.

The contract method has been used successfully during the last ten years for the extension of mains beyond the city limits. The department has entered into approximately 90 separate contracts. As the contract states, at the end of a twelve-year period all of these water mains become the property of the city and are considered a part of its distribution system.

Rates

Springfield has the same rates for water outside and inside the city limits. Although the problem has often been discussed, the rates outside the city have not been increased because the electric rate policy followed that of a competing private company. It is doubtful if there will be a change as long as this situation exists.

M. B. Cunningham

Supt. and Engr., Water Dept., Oklahoma City, Okla.

Since 1934 the construction cost of new water mains for the Oklahoma City area has been paid for by the customers or the developer. This cost is then refunded from gross revenue. Except for changes made to conform to the budget or to state laws, the plan has remained basically the same and is used both inside and outside the corporate limits of the city.

Because of the demand for water in suburban areas, Oklahoma City has found it necessary to adopt the present plan in order to avoid serving a large number of small private systems. No money from taxes, bonds or general revenue budget funds is available for construction in suburban areas, nor does Oklahoma have a revenue bond law. Although the plan has been satisfactory and developers of new additions have used it without complaint, the department is still looking for a way to finance extensions into sparsely settled areas where costs would be excessive.

Operation of Plan

The developer, or a committee representing a group desiring water mains signs an agreement with the water de-

partment which states the location of the proposed construction and the steps to be taken. The city then prepares plans and specifications, at no cost to the developer, and the City Council authorizes advertising for bids on construction. Bids received are opened by the City Council and referred for tabulation and recommendations. The water department and the applicant join in recommending an award to the "lowest and best bid." The successful bid becomes the basis for the amount of construction cost to be refunded. When the applicant has deposited a certified check or performance bond in the full amount of the construction cost, as determined by the bid recommended, the applicant and the successful bidder enter into a construction contract, which the city does not sign. The successful bidder then files a performance bond for the full amount of the contract price.

The city pays for the laboratory inspection of the pipe and materials, as well as for the inspection of construction work. The city also sterilizes the mains at its own expense, including the cost of the laboratory work.

Upon completion and acceptance, the city furnishes the applicant with a certificate showing the unit construction costs and final estimates. The applicant pays the contractor, and bonds or checks deposited with the city are returned when the receipted paid invoice is received. The city and the applicant then sign a lease agreement and contract to purchase. After approval by the City Council, the water department takes over the main extension as a part of the distribution system.

Annual refunds are made to the applicant beginning with the first year in which the gross revenue from water sales resulting from the extension amounts to not less than 10 per cent of the construction cost. These payments are continued until 100 per cent of the construction cost, without interest, has been refunded. Fifty per cent of the gross revenue is refunded annually.

Because, under Oklahoma law, the city cannot commit revenues from the succeeding year, the contracts are written to expire on June 30 of each fiscal year and continue in force by mutual agreement for not more than ten years. The budget laws require all funds to be spent for the purposes appropriated and all budget procedures must be followed. Books are therefore kept on each of these districts, accounts are closed about May 1 each year and application is made for supplemental budget funds to cover the amount of refunds due. Approval is required from the City Council, the County Excise Board and the State Budget Office. Payments are committed on or before June 30 each year to every applicant.

Experience has shown that most of these districts pay out in five years. Approximately $400,000 in construction has been handled under this plan during the past two years.

The department no longer accepts new contracts for water service in suburban areas unless water mains are constructed conforming to its specifications. No new contracts are taken for private lines or water resale districts, because the department feels that it must control the water main to enforce the plumbing ordinances, thereby reducing such hazards to public health as back-siphonage and cross-connections. The same health protection measures and plumbing inspection are applied to any connection to the system, whether inside or outside the city.

Water rates for all customers outside the corporate limits are equal to the

city rate plus 50 per cent, for the first 500,000 gal. a month. Above that quantity the rates are the same as inside the city.

C. M. McCord

Director, Water Div., Memphis Light, Gas and Water Div., Memphis, Tenn.

It is the author's opinion that a municipally owned water department is not obligated to serve an area beyond the city limits. Should usage within the city tax the facilities of the system, it would appear that service beyond the city is a very questionable procedure. On the other hand, if the supply is in excess of city requirements, it would appear reasonable to adopt a policy of water main extensions in territory immediately adjacent to the city limits that is likely to be taken into the city in the foreseeable future. The charges for service and facilities must not, however, impose a burden on the utility and its patrons. It is to the interest of the community, the city and the utility to develop the water distribution system in the fringe of the city at the time the fringe is being created. This often permits the installation of mains and services before streets have been surfaced. Such a procedure also allows the utility to make these installations in an easy, gradual manner.

When the city limits are extended, much of the annexed territory will have already been provided with necessary water facilities, thus reducing to a minimum the financial and physical shock to a utility incident to enlarging the city area.

Zoning

For the purpose of making extensions outside of the city, the territory beyond the city limits should be divided into at least three sections. That territory immediately adjacent to the city, and which will probably be first to come into the city, would be Zone 1. Extensions would be less expensive to interested parties in this area than in Zones 2 and 3. Likewise, extensions in Zone 2 would be less expensive to the developer than those in the more remote territory of Zone 3. For instance, in Zone 1 the developer would put up a cash deposit to cover the estimated cost of the extension, plus an additional sum to meet part of the cost of feeder mains. It would seem reasonable to refund the cost of the extension by allowing a credit of the cost of so many feet of main per connection. In Zone 2 the promoter would be required to put up a cash deposit equaling the estimated cost of the extension, plus an additional sum to cover all of the estimated cost of feeder mains. The extension deposit in this zone probably should be refunded as in Zone 1. In Zone 3 the interested parties would pay the estimated cost of the extension, plus the estimated cost of feeder mains, and would receive no refund of any character.

Rates

The subject of rates to be charged in areas outside of the city can be treated in a general manner only, since water rates within the city vary widely in different localities. Sometimes the rates are fixed to bring in a specified amount of revenue which may or may not be sufficient to pay all the cost incident to furnishing the service. It seems equitable for a customer outside the city to pay a rate sufficient to meet all the costs of water delivered to him, while providing a reasonable profit to the supplier. Although the author has advocated dividing the ter-

ritory beyond the city limits into three zones, more than one extramunicipal rate is not recommended unless justified by special conditions.

H. B. Miles

Gen. Mgr., Board of Water Supply, Utica, N.Y.

The water main extension policy of Utica, N.Y., is applicable to the territory outside of the city and to the five incorporated villages and fifteen established water districts in the various towns furnished with water by the Utica system. The city will extend its mains in public streets and highways immediately adjacent to existing mains at the rate of 50 lin.ft. per customer ready to serve. The cost of any excess footage required is contributed by the customer in advance at the estimated cost per linear foot for 6-in. mains. The city refunds to the contributor an amount equal to the original estimated cost of 50 lin.ft., for each new customer who connects to and uses water from that portion of the extension which is represented by the contribution. These refunds continue for a period of five years from the date the extension is completed, or until the contribution is repaid without interest, whichever is earlier. After the expiration of the five-year period, any balance of the contribution then remaining with the city and not repaid becomes the sole property of the city, which has no liability or obligation to refund or account for it. Extensions installed under this policy are owned, maintained and fully controlled by the city.

New customers are not favored at the expense of existing customers, as the revenue from the established meter rates provides the approximate amount of the carrying charges on the city's investment. Should construction costs continue upward, however, the existing alowance of 50 lin.ft. per customer may have to be reduced.

Water main extensions are installed in the incorporated villages and water districts under agreements with the respective governing bodies. The latter agree to pay the established public fire protection annual rate of 1¢ per inch-foot of main within the village or district, plus $12.00 a year for each fire hydrant.

W. C. Morse

Supt., Water Dept., Seattle, Wash.

The problem of service extensions to suburban areas involves the consideration of several questions: Are new main extensions inside the city paid for by the water department, by assessment against abutting property, by a combination of these two methods, or by some other means? Is the suburban extension required by a developer to serve a new district; to serve an already densely populated area which is inadequately supplied; or to serve the domestic demand of a thinly populated area, with or without volume sufficient for partial or complete fire protection?

No single policy can be universally adopted that will suit all of these varied conditions. Any city, however, can develop a policy that will fit in with the methods used for extensions within the city, provided it is varied to meet the conditions prevailing in the new area to be served. Once adopted, the policy can easily become standard practice for that city.

Seattle Rules

A description of Seattle's rules for suburban extensions may be helpful,

not because its policy is necessarily the best one, but because it is a policy that works. All service mains within the urban distribution grid are paid for by an assessment against the abutting property, the feeder, header and supply mains being paid for by the water department. This practice has been followed by the city since municipal ownership became effective in 1890. With a policy of this kind firmly established in the city, a corresponding basic policy for outside extensions is easy to lay down and can be modified to suit the conditions in any of the extension areas.

When a developer makes application for the service of a new district, plans are drawn showing the location and size of the mains required within the area when fully developed and occupied, and also the location of the feeder main if required. The developer, at his own cost, then constructs, or has constructed, the area system in accordance with water department standards and pays the cost of connecting it to the existing mains. This includes the cost, if any, of a feeder main of sufficient size to serve the area.

With the installation completed and the physical and sanitary inspection effected, the water is turned on after a bill-of-sale covering the entire installation has been received. Then, and not until then, is water served through the new main extension. An exception to this rule is made when the developer owns property on only one side of a street in which a main is installed. The water department will carry a portion of the cost of that particular main. The water department share—never more than 40 per cent—is determined by the judgment of the Superintendent of Water based on the anticipated return in ten years from frontage charges for new connections on the side of the street not owned by the developer.

When a densely populated area, inadequately served through a net of small pipes, requests the installation of standard mains, a survey is made by the department, together with an itemized estimate of the cost. If it is found that the number of users within the district is sufficient to return the cost—including interest at 4 per cent—in approximately ten years, by adding $1.00 a month to each user's water bill, then the work may be ordered and paid for by the water department. A hearing is first held, at which a full explanation is given and any protests are entertained. A large number of districts adjacent to the city have been served satisfactorily in this manner. Because there is no lien against the property served, care and judgment must be used by the department in estimating both for probable additional users and for probable vacancies which would reduce the monthly collections, making it necessary to continue the $1.00 charge for a prolonged period in order to return the cost of installation.

When a thinly populated area is either not served at all with city water or is served through small and inadequate pipes, the owners and residents may petition for mains of adequate, but not necessarily standard, size. Again an estimate of cost is made, the probable total of future users is computed, and a sum equal to the estimated cost is divided on a presently occupied front-foot basis. Each property then pays the amount charged to it either in cash or in ten quarterly payments.

This plan is well accepted by the people involved. Of the 38 installations made in this manner, costing $213,000, 84 per cent has been paid in, with less than one-half of one per

cent of the scheduled money payments remaining overdue.

Although the policies outlined are believed sound as they apply to Seattle, they may seem harsh indeed to water officials of cities where mains are installed at the department's cost, relying for reimbursement on additional water sales. These policies certainly protect the financial structure of the water department, preventing overexpansion and a shortage of funds, which means higher rates.

Because of the different methods used in financing main installations within various cities, uniform rules for outside service extensions, regardless of desirability, cannot be generally adopted.

Paul Weir

Gen. Mgr., Water Works, Atlanta, Ga.

The Atlanta, Ga., water supply, which is municipally owned and operated, provides 50 mgd. to 450,000 people in portions of four counties and six communities. Approximately 100,000 of these live outside the city limits.

There are two plans for service outside of the city: Plan *A*—wholesaling, or master metering, at city limits to incorporated communities (the Atlanta supply is 100 per cent metered); and Plan *B*—retailing customer service to individual applicants in nonincorporated county areas. All suburban water main extensions are paid for in advance and become the property of the city of Atlanta when laid. A minimum meter installation charge of $60.00 is made in addition to the cost of extending the service main. Water rates outside the city limits are double those inside the city. A minimum charge of $2.00 a month entitles the suburban consumer to 6,000 gal. of water.

Water main extensions in unincorporated areas are based on two factors —the size of the main and the length of the extension. There are usually three categories of water main sizes stipulated for service extensions: (1) 2-in. galvanized pipe and smaller sizes, rendering nonfire service; (2) 6-in. cast-iron mains, suitable for furnishing fire service; and (3) cast-iron mains larger than 6 in. in diameter, used as feeder mains.

The entire cost of laying 2-in. galvanized pipe, and smaller sizes, is usualy defrayed by the applicant. A 6-in. cast-iron water main, suitable for fire service, is normally installed under a three-party agreement, by which the city of Atlanta engineers the project, orders the material and makes the installation; the county opens and closes the trench; and the applicant pays the cost of all material.

Frequently an individual or real estate developer desires to extend a water main some distance beyond abutting property, other than his own, before reaching his development. Such a developer pays the cost of all material, as in Plan *B*, but is allowed tapping charges paid by others not to exceed his original material cost. Water main extensions with pipe larger than 6 in. may include a combination of the *A* and *B* Plans, plus a partial or completely financed participation by the county government.

The department has adjusted its policy on suburban water main extensions from time to time, to cope with the ever increasing demand for service. It must be remembered that the citizens of Atlanta have enlarged the water department through the years by means of their tax support of capital investment. Therefore, the department believes that an equitable program for

financing and installing suburban water main extensions should include a uniform policy which is fair and just to old and new customers alike, while rendering service at the lowest reasonable cost.

W. C. Wills

Mgr. and Chief Engr., Water Dept., Wilmington, Del.

Responsible city officials and interested citizens blow hot and cold in their support of the extension of municipal water supplies to suburban areas. At times prolonged drought, delayed expansion or serious breakdowns affect suburban water supplies. Then a dramatic effort to extend city relief on a large scale gains instant support. Occasions also arise when, because of increased revenue, a suburban extension program receives ready approval. On the other hand, programs involving sizable capital expenditures in the mains, pumps, and filters necessary for a city water system are sometimes vigorously opposed, being attributed to the need for maintaining and expanding supplies to outside areas. So the water works manager, in conscientiously reaching out for the city's future taxpayers, freely gains support for urban extensions and is restricted in suburban ones.

Wilmington, Del., by state enactment, may at its discretion distribute water throughout all the territory included within ten miles of the city boundary. Accordingly, the city extends service to approximately 3,600 accounts, 28 of which are large customers. Rates for water service outside the corporate limits are double those within, except for manufacturers, whose rates are the same as in the city.

The current city tax in Wilmington is $2.07 a hundred, including 68¢ for school purposes, as compared with 50¢ a hundred for the county area. Naturally this difference encourages, to a very great extent, building in the county and prevents the extension of city boundaries, with a resultant loss of revenue to the city. Criticism is therefore frequently voiced against granting aid to suburban communities by the extension of city facilities.

Proceeding with a middle-of-the-road pattern and a broad conception of the comprehensive problem, Wilmington during the past 20 years has laid a good groundwork by extending 12-in. feeder mains—with state and federal aid—radiating from the city proper in three favorable directions. The district surrounding Wilmington is fairly uniform in width and the city itself is regular in shape. By adhering to a broad and coordinated plan, 8-in. and smaller loops of 6-in. distributing mains have been extended from these feeders. Mains have been sized for the ultimate goal of adequate fire protection, instead of following the line of least resistance and resorting to smaller sizes.

All outside extensions are now made at the expense of the applicant, and the ownership of all mains and facilities within the public highway is vested in the city. Installations are made by the city or by a private contractor following city specifications. A common form of agreement is used, providing in general for city ownership of facilities, jurisdiction and control over the extension, rights-of-way, changes in rate schedules and changes in state and city enactments.

Except in dire emergencies, aid to private water companies is discouraged. Even when supplies have been extended to private water companies, the city has

made individual contracts directly with the users. Any service charge by the private company has been independent of the water rent assessed and collected by the city. On one occasion many years ago the city retained by agreement first option on the use or purchase of a private distribution system for a large new housing development.

Rates

The rate structure should certainly provide adequate revenue from the combined urban and suburban areas to show a reasonable profit after meeting total operation, depreciation and interest charges. To obtain this profit, it seems that a considerable surcharge should be applied, in view of the comparatively very low local county tax rate and the use of extensively developed water works to furnish service to such areas. Such a surcharge is especially justified when it is commensurate with the rates of adjacent private companies.

APPENDIX

Water Main Extension Contract

This agreement made and entered into as of this ...... day of 19...., by and between the City of Springfield, Illinois, hereinafter called "City" and ...., hereinafter called "Customer," witnesseth, That:

For and in consideration of the sum of $...... paid to the City by the Customer, receipt of which is hereby acknowledged, being at the rate of $...... per linear foot for the construction of approximately ...... feet of water main to be extended along the street or highway known as .... and shown by plat of drawing hereto attached and made a part hereof, the City agrees to construct said water main, to supervise the installation and making of all necessary connections and tests in the proposed main. The laying and extension of said main being for the special benefit of the Customer, the rules and ordinances providing for refund within the corporate limits shall not be applicable and no refund or rebate, except as herein provided, shall hereinafter be made by the said City, but said new main shall become the property of and subject to the control of said City as a part of its water distribution system.

No permit to tap said main by other persons, firms or corporations to supply property not owned by the Customer shall be granted by the City without the approval of the Customer, except upon the City being paid (in addition to its other customary charges) $...... as special compensation for each ordinary single domestic service for a property fronting not more than ...... feet on said improvement. For services of larger size, or for commercial use, or to serve property of greater frontage, a charge shall be made in proportion to the size of such service, the property to be served, and the probable use of water. In case of a disagreement between the Customer and the party or parties to be served as to the amount of compensation for such larger services, the City shall, before making such tap or connection, collect as additional special compensation whatever amount is deemed by it to be reasonable.

All sums so collected by the City as special compensation shall be paid by the City to the Customer herein annually until the Customer has received 120% of the amount paid by the Customer herein to the City or until the expiration of twelve years from the date hereof, whichever such event shall first occur; and thereafter the City may grant permits to tap or make connections to the water main without collecting said additional compensation.

The Outlook for Municipal Bonds

By Frederick L. Bird

A paper presented on May 5, 1948, at the Annual Conference, Atlantic City, N.J., by Frederick L. Bird, Director of Munic. Research, Munic. Service Dept., Dun & Bradstreet, Inc., New York.

IN recent years American water utilities have been planning several thousand capital undertakings, ranging from very formidable and expensive water supply and transmission projects to less pretentious, but still relatively costly, improvements and extensions of storage and distribution systems. It is quite obvious that such factors as the accelerated growth and shifting of population, as well as the decentralizing trend of population and industry, have not only complicated construction plans but have increased the urgency with which some of them must be carried through. The most disconcerting postwar development, however, aside from delays in obtaining materials and equipment, is the way in which inflation has played havoc with even the most carefully devised capital budgets. Every capital program which came to the author's attention during the wartime planning for postwar construction made allowances for a higher price level; but at that time and even after the close of the war there was little intimation of the degree of price inflation with which the country was to be afflicted. And over the past year or so it has been found that not only is the capital cost of improvements above reasonable expectations, but also the cost of money to finance them has nearly doubled, bringing yet another addition to operating budgets and advancing the time when rate increases will be necessary to keep water systems on a self-supporting basis.

The subject of this paper is the cost of borrowing money—what the cost seems likely to be in the immediate period ahead and what, if anything, can be done to control it.

Interest Rate Trends

The recent trend of municipal bond interest rates may be summarized briefly. Following a long downward movement in the late 1930's and early 1940's, interest rates reached their low point in the spring of 1946. In March and April of that year *The Bond Buyer's* well-known index, based on twenty-year general obligation bonds of twenty representative municipalities, showed a yield of 1.29 per cent, or not much more than half the yield on long-term United States government obligations. Thereafter interest rates began to rise—though slowly at first—until by December 1946, *The Bond Buyer's* index of yield had reached 1.90 per cent. Throughout the first ten months of 1947 the municipal bond market found stability slightly below that level, but this period was followed by sharp breaks in bond prices which raised the yield index to 2.48 per cent in February 1948—nearly twice the low point of two years earlier. In other words, the

annual interest on a $1,000,000 bond issue was $24,800 instead of the former $12,900. Since February 1948 there has been a measurable strengthening of the market, bringing the index to 2.34 per cent at the end of April. These are, of course, average figures for bonds maturing in twenty years and do not disclose the range in interest rates caused by differences in quality and in length of maturity.

There seems to be little prospect that municipal bond interest rates will move any lower. They appear to be sufficiently well stabilized at or near the present level to remain there in the immediate future. Over the longer term, however, there is the possibility of a moderate increase, as well as the probability that a greater differentiation will develop between the rates on high-grade bonds and on those which are less well secured. This situation will work to the financial disadvantage of both marginal projects financed by revenue bonds and the less favorably situated and managed municipalities. In short, it is doubtful whether a municipality will be able to borrow money any more cheaply than at present; it may be possible to borrow at, or close to, the present level for a considerable period, but this is no certainty; and sooner or later there may be a moderate interest rise, particularly if the security offered has any weak or uncertain features. The utility management is in a position, however, to exercise some control over what the future trend may be.

Future Prospects

The reasons why municipal bond interest rates have nearly doubled in the past two years provide a valuable key to future prospects. The main factor was, of course, the relation of supply and demand. In the four years 1942–45 new borrowing by states and municipalities averaged only about $310,000,000 annually after having been in the billion-dollar range for a long period. At the same time the rise in federal income tax rates greatly increased the attractiveness of tax exemption, because a man in a fairly high tax bracket could secure more "take-home" income from a 1 per cent municipal bond than from a taxable government or high-grade corporate bond. Thus, the demand exceeded the supply, which was an abnormal condition. Then, in 1946, state and municipal borrowing jumped to $1.2 billion, and in 1947 to $2.3 billion—by far the all-time high. Because the limited market provided by persons in the high income tax brackets could not begin to absorb this huge volume, municipal bond prices had to move to a level at which they would be attractive to investors with a more restricted advantage in tax exemption—mainly persons in the middle income brackets and the commercial banks. Municipal bonds had to find a new and broader market, in which there was more competition from taxable bonds, while at the same time the yield on taxable bonds was showing a moderate increase and the federal government was lowering its support level for government bonds. The entire bond market was slipping, but municipal bonds were more affected than others.

One reason why municipal bond interest rates will tend to rise in the future is the recent cut in federal income taxes, and particularly the community property provision. As well-to-do people move into lower tax brackets, it is quite evident that the tax exemption differential in favor of municipal bonds decreases. The more dominant fac-

tor, however, is the probable continuance, or even increase, of the huge volume of borrowing, as the tremendous amount of planned public works reaches the financing stage. It is quite conceivable that the volume of borrowing will more than supply the demand for tax exempt bonds and make it necessary for municipal bonds to seek a market in which tax exemption is not a consideration—namely, the insurance companies and the savings banks, which formerly were large investors in municipals but more recently have found them too expensive. This would bring municipal bonds into direct price competition with corporate bonds, which, in the high-grade classification, now sell, on a long-term basis, in the 2.75–3 per cent range.

In any event, and irrespective of the value of the tax exemption differential, the interest rate that can be secured on a particular issue of municipal bonds will be influenced very strongly by the quality of the bonds and how well that quality is appreciated by investors. In the month of April 1948, for example, municipal bonds maturing in twenty years sold with a rate as low as 1.65 and as high as 4 per cent. This discrimination, moreover, is bound to increase as a wider and wider selection of bonds becomes available for investment, as investors begin to worry about the rise in the municipal debt, and as warnings begin to accumulate about the termination of the postwar boom. It is in this field of bond quality, and of good public relations with investors, that issuers of municipal securities have an excellent opportunity to influence interest rates. Some public officials are utilizing this opportunity very advantageously; others, often through lack of experience in the marketing of bonds, are involving their municipal governments in unnecessary expense.

Sales Promotion

The principle of prime importance in planning a bond issue is to offer the very best security possible. Since the utility intends to meet the obligations, it loses nothing, but gains financially, by giving every reasonable pledge of security that will impress the prospective investor. Water bonds, because they represent an absolute necessity of the community and because they are for a revenue-producing enterprise which can be made to support itself, can be provided with exceptional security factors to obtain for them a lower interest rate than that on the general-purpose bonds of the municipality. Good judgment, careful planning and expert advice are required, however.

If it is decided to issue revenue bonds, it will be wise to employ the services of a genuine planning expert in that field and of a bond attorney who is a specialist in revenue bonds, because the technical proceedings involved call for a high degree of precision. But there is no inherent virtue in revenue bonds. A utility may be impelled to use them because the local bond laws of the state are so deficient as to leave little choice, or for other good or necessary reasons; but a financially sound municipality usually can sell its general obligation bonds to better advantage than its revenue bonds. And the cheapest method of financing a self-liquidating water system, by a municipality whose credit is sound, is the sale of bonds which carry a pledge both of the taxing power and of earnings. Water bond financing in a number of states, unfortunately, is

handicapped by laws that are not conducive to the most efficient results.

It seems reasonable that a self-supporting municipal water system should take advantage of its status to secure specially favorable interest rates on its bonds. But it is not in a position to do this if its financial administration is defective. Among the essentials of sound financial administration are the segregation and safeguarding of water funds under statutory or charter provisions, the maintenance of a standard system of municipal utility accounting in accordance with the principles recommended by the Association, the charging of other departments and agencies at standard rates for services rendered and payment for services received, and the annual publication of financial statements which disclose clearly the system's financial status. Hundreds of municipal water systems may be cited which meet all or most of such standards well; but scores of others could be named, including some of the largest in the country, which make little or no pretense of meeting any of them. The maintenance of such standards, it may be added, is not only prerequisite to securing special investor consideration of water bonds, but is also evidence of good city management which contributes to the general credit of the municipality.

While on the subject of management, however, it is worth noting that too much management can be as expensive as too little. The increasingly popular so-called municipal authorities seem to be redundant and superfluous when they do nothing more than manage what is merely a municipal water department. Authorities do serve a most useful financial and administrative purpose, however, when they facilitate the undertaking of unified water projects by metropolitan areas or groups of municipalities.

A municipality proposing to sell its water bonds must remember that it pays to advertise. If it wants to secure wide competition on the most favorable basis, the municipality should provide full information about the quality of the product. It should do so voluntarily and sufficiently well in advance of the date set for the sale to give prospective bidders an opportunity to study the data and to prepare promotional material for their own customers. From the investor's point of view, such a policy makes good sense, since he is not up to date on the geography and postwar economy of the many hundreds of political subdivisions that are rushing to sell bonds. The local chamber of commerce should cooperate by presenting attractively some current facts about the community. The investor would like to know something about the physical characteristics of the water system and what the new money is to be used for, and he will be impressed by such evidences of good management and fiscal ability as the accounting statements previously mentioned.

These are merely suggestions for sales promotion methods that some municipalities employ extraordinarily well and others only in the most perfunctory fashion or not at all. For example, the author has before him a municipal bond prospectus from a distant town which is so convincingly attractive and informative that it leaves no question about the high quality of the forthcoming bonds. Also on the author's desk is the expense account of a staff member who had to travel 2,000

miles to secure, for a new bond issue, some water system operating figures which could readily have been mailed in, if the books of account had not been in poor condition and the finance officer himself somewhat dubious about their interpretation. Careful planning and publicity for a bond issue may not produce the desired results every time, but the prospects are always sufficiently good to justify the effort.

Conclusion

Despite the improbability of lower municipal bond interest rates and the possibility of higher rates if the volume of new borrowing tends to increase, the author feels that many municipalities are paying a higher interest rate on their borrowings than is called for by the quality of their credit. He believes that there is an undeveloped, or at least only a partially developed, market for municipal bonds among persons in the medium income tax brackets who would benefit financially from the tax exemption afforded but who have never owned municipal bonds, know little about them and, in fact, have very hazy—and possibly prejudiced—views about municipal government and finance. If this large group could be reached, it might so broaden the market for tax exempt securities as to stabilize interest rates in the face of high-level borrowing. But most of the effort for any such achievement must come from the municipalities themselves, through better public reporting and public relations which will develop more understanding of, and confidence in, municipal affairs.

Erratum

In the paper "Problems in Cathodic Protection" by Frank E. Dolson (Vol. 39, p. 1079, November 1947 JOURNAL), an editorial error altered the author's meaning. The first paragraph, which now reads:

> When two dissimilar metals are buried in a suitable electrolyte, an electric current is caused to flow. The more noble metal becomes the cathode, the less noble the anode. Zinc and iron buried in soil and connected together by an external wire would cause a current to flow. Through the soil the flow of current would be from zinc (cathode) to iron (anode) and through the external circuit from iron to zinc. This is similar to the flow of current in a common dry cell. In the conventional sense, current flows from the positive pole (carbon, anode) through the external circuit to the negative terminal (zinc, cathode) and within the electrolyte from the zinc to the carbon.

should have read:

> When two dissimilar metals are buried in a suitable electrolyte, an electric current is caused to flow. The more noble metal becomes the cathode, the less noble the anode. Zinc and iron buried in soil and connected together by an external wire would cause a current to flow. Through the soil the flow of current would be from zinc (anode) to iron (cathode) and through the external circuit from iron to zinc. This is similar to the flow of current in a common dry cell. In the conventional sense, current flows from the positive pole (carbon, cathode) through the external circuit to the negative terminal (zinc, anode) and within the electrolyte from the zinc to the carbon.

Pumping Stations for the Medium-Size City

By Francis S. Friel

A paper presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., by Francis S. Friel, Pres., Albright & Friel Inc., Philadelphia.

IN considering the approach to the subject of pumping station design for medium-size cities, it might be interesting to mention the conditions existing in Philadelphia some 160 years ago, when that municipality was a city of medium size with a water pumping problem.

The will of Benjamin Franklin, who died in 1790, provided a water supply for Philadelphia by earmarking part of £100,000 for the construction of a pipeline to convey water from Wissahickon Creek into the city. Slightly over a decade after Franklin's death, Philadelphia planned and started to build its first water supply. In 1801 a supply was developed along the banks of the Schuylkill, the raw water being conveyed from the river through a subterranean rock-filled tunnel, 6 ft. in diameter and 300 ft. long, and pumped approximately 4,200 ft. to the site of the present City Hall in "Center Square." There a so-called "booster station" was constructed, equipped with a double steam engine having a cylinder 32 in. in diameter and a 6-ft. stroke. At the rate of twelve strokes per minute, the pump had an estimated capacity of 1 mil.gal. for each sixteen-hour pumping day. The water was lifted by this pump to wooden tanks located 36 ft. above the surface of the street and then conveyed by gravity through the wood main distribution system. The low-duty pumping station, located along the Schuylkill, was similar in type to the Center Square Station.

To construct this system, Philadelphia floated a loan of $150,000, which was secured by the corporate property of the city. History shows that the city fathers evidently had trouble in making this loan because there was doubt concerning the practicability of a steam-driven pump. Previous attempts to use steam for pumping water had failed, and Philadelphia claims to be the first city to employ this type of motive power.

The original Center Square Pumping Station was able to keep up with the rapidly increasing growth of the city until 1815, when the original plant was discontinued after 14 years of operation and the Fairmount Pumping Station was constructed. During this period, however, the steam-driven pump was proved to be practical.

In the span of 147 years since the installation of this original pumping station, the water demand in Philadelphia has grown from 1 mgd. to approximately 350.

Centrifugal Pumps

This paper will discuss the centrifugal pump—the type generally in service in distribution systems today—as well as other kinds of pumps and their use to meet the demands of the me-

dium-size city for both low- and high-duty pumping.

The centrifugal pump is such a small piece of equipment in comparison with its predecessor, the reciprocating pump, that the problem of locating it in a station, especially one which was laid out originally for reciprocating pumps, is usually quite simple. There is generally plenty of room in a station of this kind for the installation of many more centrifugal pumps than are actually needed.

Because of the surprisingly large number of new pumps which can be installed in rooms built for big steam-driven reciprocating pumps, a city can extend its pumping capacity greatly without making additions to existing pumping stations. At the Godwin Street Pumping Station in Portsmouth, Va., for example, the present combined capacity of the centrifugal pumps is 34.6 mgd., although the station was intended for 18.5 mgd. of reciprocating pump capacity.

Pumping Station Design

In designing a new pumping station, however, the problem is considerably different, particularly with the present high cost of construction. It is usually economical, from the standpoint of both construction and operation costs, to take advantage of the small size of the centrifugal pump and its compact drive. The modern trend is also toward the totally enclosed type of switchgear, which likewise minimizes the space requirements. A recent layout, prepared under the author's direction for the Chester Municipal Authority at Chester, Pa., will serve as an example.

This project, which is now under construction, consists of an impounding reservoir; a water filtration plant, with a rated capacity of 18 mil.gal.; and a 40-mile pipeline from the filter plant to the city. The water flows from the reservoir to the filter plant by gravity and is lifted to the system by high-duty, horizontal, centrifugal motor-driven pumps in series, with bottom suction and side discharge. An electrically-hydraulically operated cone valve is located on the discharge line of each pump, and, in addition, another cone valve is placed on the 42-in. discharge main in the throat of the Venturi tube. The pumping station has a total capacity of 36 mgd. and is equipped with four pumps having capacities of 6, 8, 10 and 12 mgd. The varied capacity of the individual pumps makes possible a pumping range of 6 to 30 mgd., at intervals of 2 mgd.

The filter plant at Chester is designed with six 3-mgd. filter units. When the pumping demand is low, instead of shutting off individual filters, the rate through the six filters will be reduced in multiples of 2 mgd., thus synchronizing the production of water with the pumping requirements.

There are several other items of interest in the design of this pumping station. The first is the absence of piping on the pump floor. A pipe gallery has been provided in the basement below, an arrangement which permits the utilization of a minimum-size structure and provides a pleasing appearance. Provision is also made for a trolley beam, equipped with a hoist, located over the centerline of each unit, for removing the pump casings and maintaining the equipment. The interior ceiling of the station is lined with acoustical material, in accordance with modern practice.

The switchgear for the electric motors is of the totally enclosed, dead-front, metal-clad type. It consists of a

box structure containing circuit breakers and associated equipment—such as instrument transformers, buses and connections—and individual sections containing motor starters and feeder circuits.

The station has been laid out in such a manner that, if required in the future, the 6-mgd. unit which will now be installed can be replaced with a 14-mgd. unit, thus providing a total pumping capacity of 44 mgd. This will make possible the enlargement of the filter capacity of the plant up to 50 per cent of its present design capacity, without adding more pumproom space.

A typical method of arranging high-duty pumps is illustrated in Fig. 1, which shows the system used in a plant designed by the author at the Philadelphia Navy Yard. There are three pumps with capacities of 4.8, 6.0 and 7.5 mgd., respectively, the 6-mgd. pump being equipped with a stand-by gasoline engine. It will be noted that the three pumps discharge to a common header, which, in turn, forms a loop.

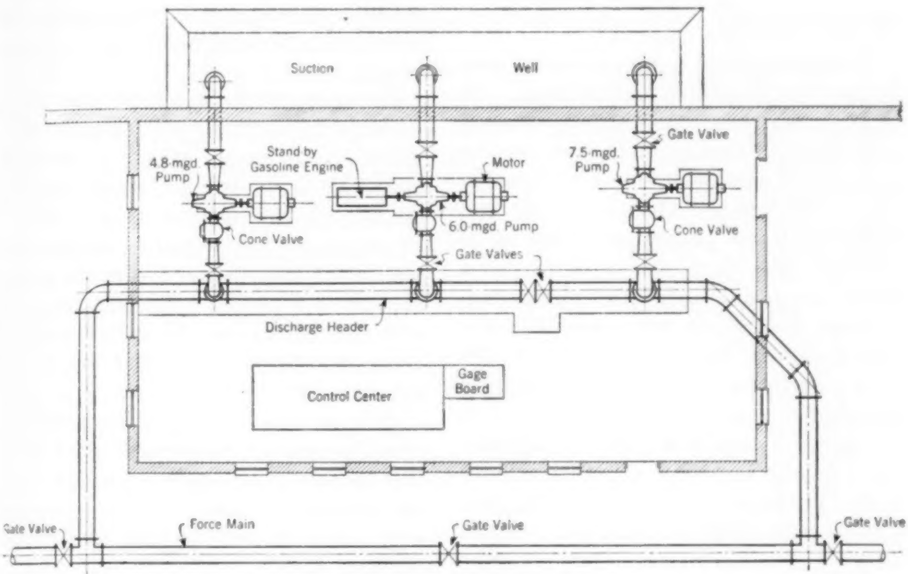

Fig. 1. Typical Pumping Station Layout

Low-Duty Layouts

Several combinations of single-stage centrifugal pumps are suitable for low-duty municipal water pumping service:

1. *Side suction–side discharge.* In order to reduce the space required by suction and discharge piping, it is sometimes desirable to install several pumps at an angle.

2. *Bottom suction–side discharge.* This unit, which is entirely free from piping on one side, appears to be the most practical for medium-size and larger pumps. Such units are available from most pump companies in standard developed sizes of approximately 3,000 gpm. and larger.

3. *Bottom suction–bottom discharge.* This arrangement results in a clean-cut

appearance on the pumproom floor but often leads to piping and foundation complications in the basement.

All of these three types of pumping units are based upon single-stage pumps, used where heads do not exceed approximately 250 ft. In units with larger capacities, the heads may sometimes go as high as 350 ft. and still permit the use of a single-casing pump.

Series Pumping

Two centrifugal pumps in series may be used for handling higher heads. In larger sizes, these units are now almost entirely furnished with bottom suction and side discharge in order to simplify the series piping which may be run underneath the pumproom floor, as at Chester, Pa. It is awkward to use a side suction–side discharge pump, but, if local conditions are such that the series piping cannot go beneath the floor, such an arrangement becomes necessary. In smaller units—say, up to about 5 mgd.—the pump builders have greatly improved the efficiencies of their two-stage single-casing units, thus allowing an even more compact station arrangement.

Generally, the motor is at the end of multiple-casing series pumping units, although sometimes the most economical arrangement is to have the motor in between the series pumps. For unusually high heads, three pumps are occasionally connected in series.

Steam-Turbine Drive

The majority of the examples given have illustrated motor-driven units, which are the most widely used. With the trend toward higher fuel and labor costs and with the electric utilities doing such a good job of keeping power costs down, the electric motor will probably continue to be the first choice for the pump drive. The geared steam turbine, however, is still frequently employed. It has the great advantage of an easily adjustable speed, so that the head and capacity can readily be varied to suit the system head-capacity curve. This advantage is not to be found in the squirrel-cage induction motor and the synchronous motor, but it is possible to obtain it by using a variable-speed hydraulic or electric coupling between the constant-speed motor and the pump.

In comparing steam-turbine drive with electric operation, the greater flexibility of the former cannot be ignored. In water works service, when pumping directly to the system, there exists a variation not only in the demand, but also in the pressures. Under these conditions, the turbine-driven unit, because its speed can be varied without seriously affecting its efficiency, makes the best installation.

It is at times desirable to provide a stand-by source of power. The gasoline engine is well suited for this service because of its compact size, low cost, ease of maintenance and quick-starting ability.

Improvements in Efficiency

Advances have been made in the efficiency of the centrifugal pump. Thirty years ago an efficiency of 80 per cent was considered good, while today pumps are expected to have efficiencies close to 90 per cent.

During the past thirty years improvements in efficiency have also been made in the electric motor and the steam turbine. Extremely high motor efficiencies are now being obtained even from comparatively small motors. For instance, efficiencies from 95.5 up to 97

per cent have been achieved in synchronous motors of from 400 to 1,800 hp.

Low-Lift Pumping Units

The majority of low-lift pumps are of the horizontal type, and, because of the usually low heads, they commonly operate at low speeds. Where possible and economical, it is preferable to use horizontal low-lift pumps because of the standard drive, the greater ease of maintenance, the greater accessibility for inspecting and replacing parts, and the generally more satisfactory operation of bearings and packing boxes. There are many places, however, where the vertical pump has a definite value in a municipal pumping system. Stations subject to flooding may use vertical units so that the electrical equipment can be located above flood stage.

For the larger sizes of vertical pumps, the double-suction type may become too cumbersome and, because it is a low-speed machine, the size and cost of the pump and driver may be too great on low-head applications. In such situations, there have been many installations of vertical mixed-flow pumps.

Electrical Equipment

The principal items of electrical equipment associated with pumping stations are transformer substations and pump motors, and their control and switchgear.

Substations

The modern trend is to use outdoor substations of the unit type, embodying a compact assembly of a polyphase transformer, high- and low-voltage lightning protectors, high-voltage protective links and a low-voltage circuit breaker. The functions of transformation, protection, control and metering of electric power, performed by separate pieces of apparatus in the open-structure type of substation, are all combined in a completely enclosed, factory-assembled, wired and tested unit substation including all necessary auxiliary equipment for its operation.

Motors

The alternating current motors most suitable for pump drives are the induction type—squirrel-cage or wound-rotor—and the synchronous type. All may be obtained for either vertical or horizontal mounting. Squirrel-cage induction motors and synchronous motors are used for constant-speed drives.

TABLE 1

Basic Motor Data

Item	Motor Type	
	Squirrel Cage	Synchronous
Speed—rpm.	880	900
Price—$		
Motor	3,941	3,597
Exciter		449
Control	2,247	2,699
TOTAL	6,188	6,745
Efficiency—%		
½	91.6	92.7
¾	92.9	94.1
4/4	93.1	94.7
Power factor—%		
½	80.9	85.0*
¾	86	95*
4/4	89.4	100

* Leading power factor.

Fundamental economics involving initial costs and operating and maintenance expenses, together with the rules and regulations of the local power company, should be taken into consideration in selecting the type of motor for a

particular application. Table 1 contains the basic data which are normally required in order to select a type of motor. This information relates to a standard 500-hp., 900-rpm. (synchronous speed), 2300-v., three-phase, 60-cycle, 40°-rise, horizontal, open-type motor. The controller is of the full-voltage, magnetic type.

The summary in Table 1 indicates a \$557 advantage in favor of the squirrel-cage motor. If the synchronous motor were purchased, this difference in first cost could be saved in the cost of power within less than five years, on the basis of 360 days' operation at 24 hours a day and power at 1¢ per kilowatt-hour. Furthermore, operating with a 100 per cent power factor, as does the synchronous motor, there would be no penalty for a low power factor, which in many localities would introduce an appreciable saving.

Maintenance cost would be in favor of the squirrel-cage motor because of the presence of collector rings and brushes on the synchronous motor and the commutator and brushes on its exciter. Normally, these additions to the maintenance cost would not offset the saving in the cost of power.

The synchronous motor has a definite speed, which does not change with load or applied voltage up to the pull-out point. It must operate at its synchronous speed or not at all. On the other hand, the squirrel-cage induction motor has a characteristic known as "slip," which usually amounts to 2.5–4 per cent with the motor operating at rated load. The speed at which the synchronous motor will operate is exactly predictable, while the speed of the induction motor is not.

The third type of motor—the wound-rotor induction type—finds its principal application in driving pumps that require speed adjustment.

Switchgear

Present-day practice in water pumping stations is to use metal-clad switchgear, which was previously described in discussing the Chester, Pa., pumping station. Being totally enclosed and dead-front, this type of switchgear insures the safety of the plant attendants. Its eye appeal is also excellent.

Conclusion

Some of the basic principles and problems involved in designing a pumping station for the medium-size city have been briefly pointed out. The advances made in the art of pumping water have been gratifying, but the water works industry must continue to advance as it has in the past. The requirements for better service at lower cost are always increasing, and the water works field must meet this challenge. Lower operating costs can be achieved by the proper selection and application of pumping equipment.

Acknowledgment

The assistance rendered by H. Kimble Hicks of the Dravo Corp. and C. F. King of Westinghouse in furnishing data for the preparation of this paper and in permitting the use of photographs is gratefully acknowledged.

A New Automatic Pressure-Flow Control System

By Marsden C. Smith

A paper presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., by Marsden C. Smith, Chief Engr., Dept. of Public Utilities, Richmond, Va.

RICHMOND, Va., by annexation, recently became responsible for the water supply in a large area west of the city, which, prior to that time, had operated as a sanitary district. Because most of the ground in this area is at higher elevations than are found in the city, booster pumps are required to raise the water. For this purpose, a new pumping station was designed to have an ultimate capacity of 16 mgd. and to take water from the Second Service Area in the old part of the city, boosting it into a new (Fourth) Service Area.

In order to relieve the Second Service Area of the high peaks in demand created in this high-valued residential area, and as a protection against pump failure, elevated storage within the new area was also required. But the topography dictated that the tank must be situated approximately 3 miles west of the required location of the pumping station. As is becoming true more and more, economy compelled the pumps to be automatically operated. Collectively, these factors created a seriously complex problem for automatic control; in fact, it was much too complicated for successful solution by any automatic control system then known to the department.

In this description of a new system of automatic control, no effort is made to examine or deride any other system. Consequently, any comparison used is solely for the purpose of aiding in a better understanding of the merits of the system discussed in this paper.

Pressure-Flow Operation

However many variations may be devised, including even remote transmission, the usual automatic pump control is actuated by pressure only. On the other hand, the new control, here described, is actuated both by pressure and by *flow*. The pressure-only and the pressure-flow automatic control systems appear quite similar but are actually vastly different.

For example, consider the basic, one-pump, operating sequences of each. In the automatic control cycle of a pressure-only system, the water pressure falls to a predetermined lowest safe value, causing the pump to start. The pump continues to operate until a predetermined higher pressure exists, which stops the pump. The pump functions without direct regard to the tank water level or to water demand, being affected only by pressure. The tank then supplies the system until the low pressure is obtained, thus completing the operating cycle.

In exactly the same way, in the automatic control cycle of the pressure-flow system, the pump is started because of reduced pressure. But the pump then continues to operate as long as it de-

livers a minimum predetermined quantity of water, regardless of the pressure in the system. Of course, should conditions require, the pump can be stopped if excessive pressures exist, but, normally, it will not stop unless the pump delivery falls below the predetermined minimum quantity of water. The tank then supplies the system until the low pressure is again obtained, and the operating cycle is completed. Some of the advantages of this method of operation, which are indeed striking, will be described below.

Efficiency

Everyone is now familiar with the relatively limited capacity range in which the centrifugal pump can operate at maximum efficiency. In general, as much as 25 per cent loss in efficiency must be allowed when such pumps are operated at 50 per cent of their design flow; and this loss increases to as much as 40 per cent when the pump operates at 25 per cent of the design flow.

With pressure-flow control, the pump, once started, is continued in operation only while its delivery is above the desired minimum, which can be regulated to a nicety. It follows, therefore, that all water pumped will be at a satisfactorily high efficiency.

Whenever the demands exceed the efficient capacity of one pump, any number of additional pumps can be automatically started and stopped as may be needed. Thus, one or all of the pumps can be operated close to their maximum efficiency. Manifestly, such a control pays dividends by reducing power costs.

Tank Size

Eleveated tanks are primarily constructed to provide service in case of pump failure. The quantity of water that must be available in the tank at the minimum normal level is, therefore, a function of the demand and the time necessary to correct the cause of pump failure and re-start the pump. For lack of a better term, this quantity of water may be called the "essential capacity" of the tank. The capacity of the tank in excess of the essential capacity is sometimes called the "working capacity" of the tank; but, since it is not always available, the term "unreliable capacity" seems entirely rational. The unreliable capacity of a tank is a function of the pump capacity, the demand and the permissible frequency of pump cycling.

Obviously, this unreliable capacity costs the same as the essential capacity and, therefore, should be reduced to the very minimum. But at the same time, because of the system disturbances and pressure variations caused by starting and stopping the pump, good service requires that a sufficient unreliable capacity must be provided to limit to a reasonable degree the frequency of pump cycling.

It is evident that, even with the pump at a standstill, the tank can never reach the lowest level when no water is being drawn from the system. Therefore, after the pump has been stopped because of decreasing demand—say, after midnight—the extremely low demand may permit the tank, despite an exceedingly small unreliable capacity, to supply the load until morning. Then, when the pump is started, the demand in the system will usually have increased to such a point that it permits the pump to continue operating efficiently. Even with an extremely small unreliable tank capacity available, a system thus controlled will cycle, at most, only a few times a day.

Since the pump will usually fill the tank before the maximum morning demand is reached, the tank is full and is

kept full so long as the capacity of the pump is greater than the demand for water. Hence, pressure-flow automatic control practically eliminates the objectionable cycling of the pump and reduces to a minimum the unreliable capacity of the tank. Unquestionably, such a control pays dividends by lowering the initial and operating cost of elevated storage tanks.

Tank Location

With the previously available methods of automatic pump control, the location of elevated storage tanks has been dictated by the limitations of the control almost as much as by topography. Better service can always be obtained when the tank is located at a distance from the pump, as heavy demands can surely be better served from two directions than from one. However, because the pressure at the pump is so greatly increased by pipe friction when the tank is far from the pump, remote control must usually be provided if automatic operation is to be successfully used.

Even when leased from a public utility, such interconnection for remote control is both expensive and relatively unreliable, being subject to total failure. Fortunately, the new pressure-flow system provides a control practically as reliable and as complete as can be obtained by the relatively very expensive manual control of pumping stations. Such a control pays dividends in increased reliability, safety from sabotage and reduction of control rental or maintenance costs.

Pressure Compensation

Another valuable advantage of this new pressure-flow control is its ability to maintain automatically pressures more nearly constant than those due to the use of pressure control only. Since under pressure-flow control the tank remains practically full at all times, even when using a constant-speed pump, the variation between the level at which the pump is started and that at which it is stopped is avoided.

What is far more important, by pressure-flow automatic control the pressure loss due to pipe friction between the pump and any selected point within the distribution system can be compensated for to any desired degree. This, of course, requires a variable-speed pump, which is made to maintain pressures less than, equal to, or actually greater than the pipe friction. In other words, the pressure at the center of the distribution system can be held almost exactly constant, within the limits of the capacity of the pumps to deliver water, regardless of the quantity being consumed. This one fact may frequently eliminate, or at least postpone, the necessity for expensive enlargement of mains between the pumping station and the center of the system. Consequently, such a control pays dividends by indirectly increasing the capacity of the distribution system.

Equipment Required

The essential parts of the simplest, one-pump, control are: (1) a pressure switch to start the pump at the minimum desired discharge pressure, and (2) an electrical contact actuated by a water-flow meter in the pump discharge. This contact continues the pump in operation after the pressure switch has opened because of the increased pressure produced by the running pump. The switch does not open again until the volume delivered by the pump falls below the desired minimum.

Although the control requires a meter to determine the flow, this is already almost a necessity in the modern pumping station, not only for the rec-

ords obtained but also to provide a ready means of determining load fluctuations, total flow and pump efficiency. Of course, if more than one pump is used, only one meter is required for the pressure-flow control, provided that a common header with a single outlet may be used.

Consequently, the only true additional cost of the pressure-flow control is the master controller, which is actuated indirectly by flow and by which, in turn, the pump motor is controlled. The controller is a relatively simple and inexpensive device and may be either pneumatically or electrically operated.

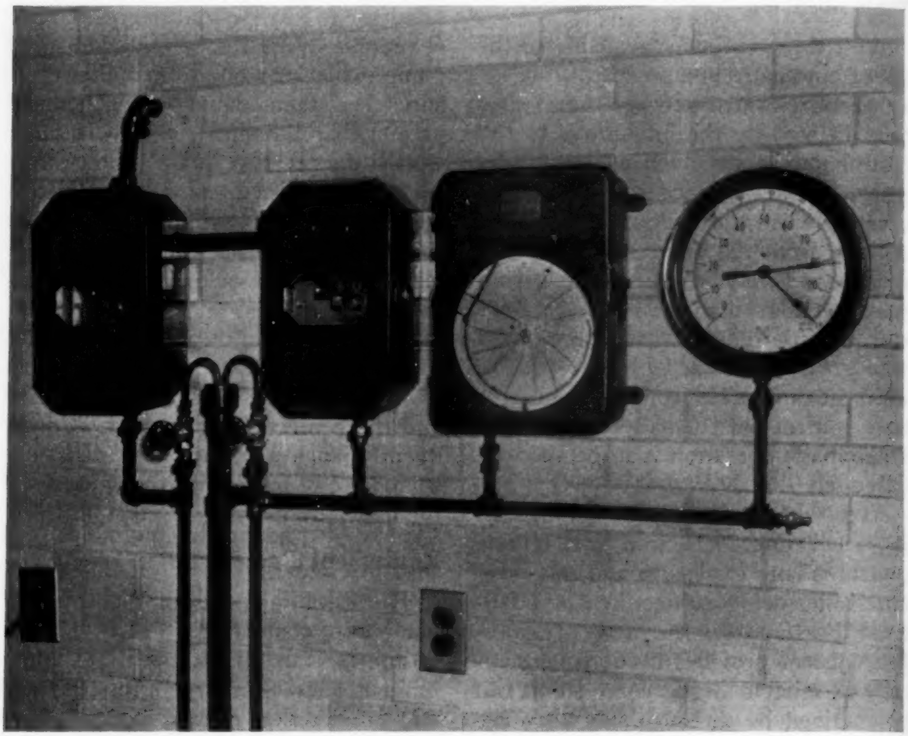

Fig. 1. Switches and Recorders

Richmond System

As has been said, the Richmond system required a much more complex control than will usually be necessary. However, it should be borne in mind that, just as the size, type and number of pumps must be determined for each station by the conditions to be met, so the degree and complexity of the pressure-flow control is determined by necessity. The Richmond system is here described because it is so complete and shows how effectively this automatic control can function. The description is of the completed installation, although the elevated tank and the two constant-speed pumps have not yet been installed.

Because the water to be pumped is taken from the western edge of the Second Service Area, the suction pressure is subject to rather wide variations and may even fail entirely. For this

reason, a suction-pressure switch was required which prevents the Fourth Service pumps from starting and, after two minutes, will stop all pumps in the station if the suction pressure is less than 5 psig.

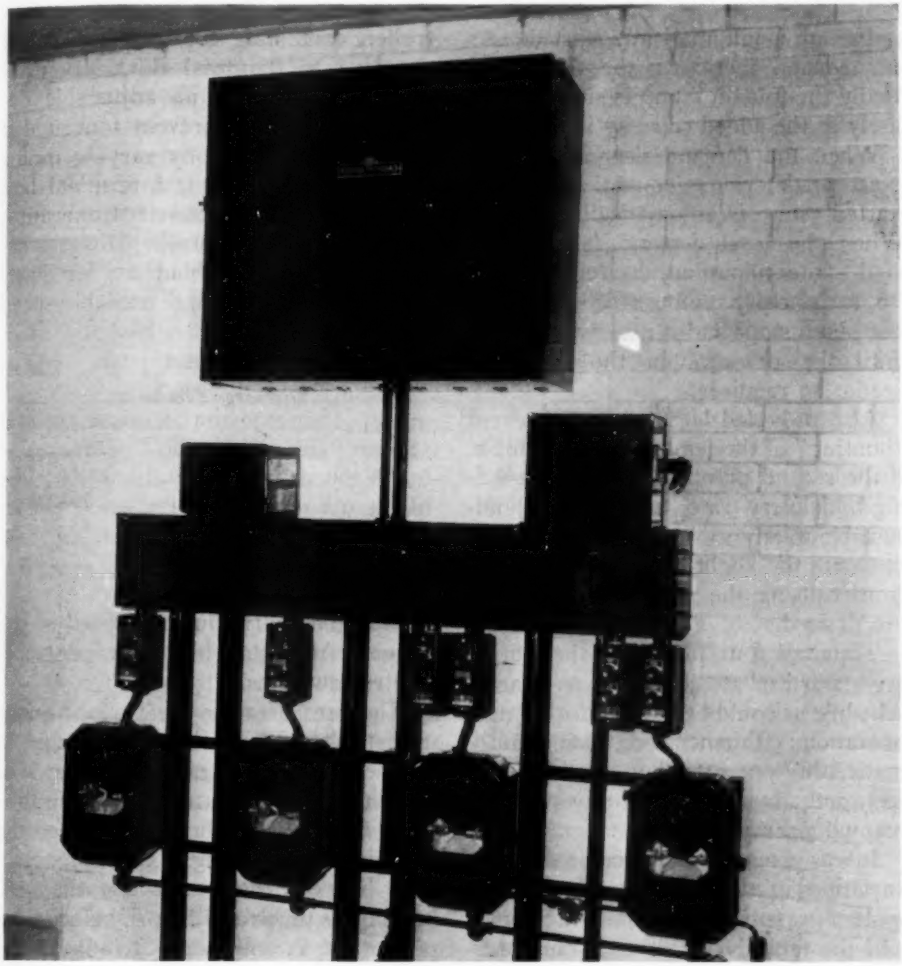

FIG. 2. Control Mechanisms

is approximately 3 miles from the pumps, this condition may occur with the tank practically full, the pressure loss being due entirely to pipe friction. But a pressure loss of as much as 10 ft. in the water distribution system can-

To start the first pump, there is provided a discharge-pressure switch, adjusted so that after two minutes it will start a variable-speed pump when the pressure at the station falls to 10 ft. below the full tank level. Since the tank

not exist unless water is being used at a rate in excess of 2 mgd., which is 50 per cent of the full load capacity of one pump. The use of the water *from the system* is thus high enough to permit the pump to operate efficiently, and

this it will continue to do, regardless of the discharge pressure, until the delivery of the pump falls to a rate of 2.0 mgd., the lowest desired quantity.

If the quantity of water required by the distribution system—whether for consumption or for filling the tank or both—should exceed 4.5 mgd., a second pump is automatically started. As the demand increases, the third, and finally the fourth, pump is started, precisely as the added capacity is required.

When the demand decreases to an exact predetermined quantity, the last started pump is automatically stopped. When the total demand falls to 2.0 mgd. (the minimum desired delivery for satisfactory pump efficiency), the last pump stops and is not started again until the pressure in the discharge header so requires.

Also provided is a means to prevent "hunting" of the pumps. For example, if the second pump is started at a 4.5-mgd. delivery rate, a differential adjustable to any value less than 4.5-mgd. prevents the slight fluctuations in load from causing the pump to stop when not desired.

Thus, all four pumps in the station are started or stopped upon as exact a schedule as could be devised for manual operation. Furthermore, being automatic, this pressure-flow control is, in fact, actually superior to any practical manual operation.

It was essential to overcome the wide variation in suction pressure and the system pressure loss between the pumps and the tank. To this end, four pressure-control switches are provided, each of which is adjustable as to both the range in the quantity of water being delivered and the discharge pressure maintained. Only one pressure switch is in control of the pressure for any total quantity of water being delivered.

Figure 1, reading from left to right, shows: a low-pressure suction cutout switch; a discharge-pressure switch; an outlet-pressure recorder (the uniformity indicates that the photograph was taken on a day of relatively light loads); and a discharge-pressure gage. At the top of Fig. 2 is a master controller, containing control switches responsive to the total flow. Beneath this, to the left, is an adjustable delay mechanism to prevent too sudden changes in pressure by varying motor speeds; to the right is a terminal box with switches to convert from automatic to manual control. Directly below are manual pushbuttons for starting the constant- and variable-speed

TABLE 1

Discharge Pressures

Pressure Switch No.	Range *mgd.*	Pressure *psi.*
1	2.0–3.0	79–82
2	3.0–4.5	83–86
3	4.5–7.8	87–90
4	over 7.8	91–94

pumps and controlling the speed of the latter. At bottom are four pressure-control switches.

The pressures for the various quantities delivered are given in Table 1. These may be changed as varying load conditions may indicate to be desirable. The static head at the pumps, when the tank is full, is 80 psig. Thus, pipe friction between the pumps and the tank may be as much as 12.5 psi. before even a full tank will begin to discharge. This compensating pressure increase could just as easily be much greater, but it was not desirable to subject the system near the pumping station to higher pressures.

There will be two variable-speed and two constant-speed pumps, each of 4-

mgd. capacity. Had greater pressure range been desired, all four pumps would have been of the variable-speed type, but at Richmond the greater reliability and lower cost of the constant-speed motors more than overcame the doubtful advantage of further increasing pressures with increasing loads. The number of pressure switches used is, of course, determined by the degree of accuracy of pressure control desired or justified.

There are other features of design that are of interest. These are not an essential part of the control but were included to provide greater reliability and uniformity of service. Each pump and motor bearing is protected by a thermostat. Should a bearing become overheated, the pump in distress is automatically stopped and a pump in reserve is started and brought to its correct speed. Fortunately, this has never been required. The same device is provided to protect each motor from damage due to overload. But, since each motor is large enough to drive its pump under any operating condition without overload, this feature is used only because it is required by safety codes. If the power has failed, the station returns to starting position as soon as it is resumed and then automatically restores normal operation.

In order to equalize the wear on the various pumps as far as their designs permit, a means of instantly changing the sequence of pump starting has been provided. This is now so connected that one week the pumps are started in the order of their numbers; by a simple turn of a switch, the next week the pumps are started with No. 2, followed by No. 1 (both variable speed), and then No. 4, followed by No. 3 (both constant speed). By simple electrical reconnections this sequence can be changed if desired.

Finally, also by a simple transfer switch, the station can be changed from full automatic to manual control without interrupting the operation.

Conclusion

From the limited description given in this paper it seems evident that the new pressure-flow control provides:

1. Maximum efficiency of pumping
2. Minimum disturbance that always results from stopping and starting the pumps
3. A material reduction in the cost of elevated storage tanks
4. Freedom to place the pumps and tanks at the most desirable location, regardless of the distance between them
5. The elimination of the necessity for remote control
6. The control of pressures at any point in the distribution system
7. The possible postponement or even the elimination of the necessity for expensive main enlargements.
8. What is probably most important, an escape from the present high cost of manual operation of pumping stations, by an automatic control that is fully as flexible and almost as reliable as manual control, and yet is without the limitations of previously available automatic systems.

Small Water Treatment Plants

By Thomas R. Lathrop

A paper presented on May 3, 1948, at the Annual Conference, Atlantic City, N.J., by Thomas R. Lathrop, Asst. Engr., State Dept. of Health, Columbus, Ohio.

TO a great extent, the problems of the small and large treatment plant are similar. The raw waters of both produce the same problems of purification, including chemical application, filtration and disinfection. The differences in operation are the result of differences in plant design and also in the type of personnel usually employed.

A plant with a capacity of 0.5 mgd. or less is considered a small plant. The plant operator usually is responsible for the entire system, from operating low-service pumps to reading the meters and sending out the bills. This discussion, then, will be confined to plants of 0.5 mgd. or less. Even in this category, many plants are provided with the same features as larger ones, and treat waters presenting similar problems of turbidity, tastes, odors, hardness and bacterial contamination. Some small plants also have well-trained operators. But differences in design, operating conditions and personnel problems do occur.

All water treatment plants constructed in Ohio must have the approval of the Ohio Dept. of Health. A few of the regulations governing these plants should be mentioned: (1) The rate of filtration required is 2 gpm. per square foot in purification plants using surface waters; 3 gpm. is permitted in softening and iron removal plants using ground waters. (2) Filter rate controllers are required on all filters. (3) Open gravity filters are required for all surface waters, but pressure filters are permitted in softening plants which treat ground waters. (4) Settling basins having at least four hours' detention are required at all plants using surface waters, although if ground waters are softened shorter detention periods are allowed.

Design Features

The construction of completely new water works including treatment plants so taxed some of the small municipalities that the water works structure was not made large enough to provide space for chemical storage. The filters reach almost to the roof, making it very difficult to get into a filter and even more difficult to remove and replace the sand and gravel. At some plants of this sort a small building adjacent to the filter building is used for storing chemicals. These arrangements add to the problems of operation.

Cylindrical steel reaction and settling tanks, which are often employed for economy's sake, usually afford rather inefficient mixing. In some plants where the lack of effective mixing has been noted, the addition of mechanical mixing devices has improved conditions. When lime-soda softening is involved, the steel tank serves as a mixing chamber, settling basin and recar-

bonation basin, with recarbonation occurring in the outtake pipe. The water is generally not stable when it reaches the filter, and the sand encrusts rapidly.

Surface washing not only keeps the sand in filters in clean condition, but in the softening plant it reduces the rate of incrustation of the sand. In the small plant, surface washing can be provided from piping which is usually on hand. A small grid of 1-in. pipe placed in such a filter makes an excellent surface washer. It is simple to construct and is so small that it can be easily handled if it becomes necessary to remove it from the filter.

Chemical application for the small plant is best provided by using solution feeding devices. Few of the dry feeders will apply chemicals accurately in the small amounts usually required. Too often the chemical storage space is in the same room as the filters and pipe gallery, where moisture conditions affect the chemicals—especially lime and soda—so that they cannot be fed accurately by any volumetric feeder. Incidentally, accuracy of chemical application is more important in the small plant than in the large one. Over- and undertreated waters are much more apt to reach consumers in small communities. In spite of this, many small plants are equipped with dry feeders which give no end of trouble.

The recarbonation of lime-softened water presents many problems in all plants, and the small plant is no exception. When natural gas is available, a gas burner is usually employed for producing carbon dioxide. Kerosene burners are generally more satisfactory in the small plant than coke burning furnaces, because operation is usually intermittent and a small coke fire is difficult to keep burning. Recarbonation units employing dry ice are of great advantage, although the cost is perhaps somewhat more than for carbon dioxide generated as a product of combustion. There is no problem of generation or compression; the dry ice is delivered in sizable blocks which are cracked up and placed in a screw-capped pressure cylinder. The gas coming from the top of the cylinder is measured by a rotameter and diffused through a fabric hose of the type used for watering flowers and sold under the name "soil soaker." Excellent results are reported. In some small lime softening plants, recarbonation is not practiced because of the difficulties involved. Vitreous phosphate * is applied in an effort to offset the effect of water saturated with calcium carbonate. This treatment prevents the incrustation of the filter sand and pipelines, but, if water is treated with excess lime, the vitreous phosphate does not remove the causticity and a caustic taste often remains.

Pressure filters are installed as an economy measure at certain small water treatment works. In Ohio, the installation of pressure filters is discouraged and such units are permitted only at plants designed for ground water softening or iron removal. Very little need be said about the disadvantages of this type of equipment. Tastes and odors at times develop in these units as a result of biological growths. The sand cements together, and overhauling the filters is a disagreeable job.

Gravity filters are occasionally constructed using steel shells, some as small as 5 or 6 ft. in diameter. Concrete units providing 25 sq.ft. of filter area are about the smallest size that should be made. Smaller units would be very difficult to work in during con-

* Produced by Calgon, Inc., of Pittsburgh, Pa., and known as "Calgon."

struction and overhauling operations.

Rate controllers are most economically constructed for one or two filters by employing a float chamber which provides a constant head over an orifice. The only problem of operation is to keep the float valve working freely. Putting a proper cover over these controllers is quite important if foreign matter is to be kept from the clear well. The type of rate controller usually supplied employs a hydraulic valve actuated by pressure on a diaphragm and is very satisfactory in the plain filtration plant. It is of little use in many lime-soda plants because the pilot becomes encrusted and the controller fails to function. If the vitreous phosphate can be introduced into the water ahead of the filters, this trouble is eliminated. However, a water harder by 20 ppm. may be expected when it is applied to the water before filtration.

Pumps in the softening plant using pressure filters usually take suction from the settling tank discharging through the filter into the distributing system. This arrangement has the serious drawback of causing incrustation of the pump runner and housing, making it necessary to take the pump out of service about once or twice a month for removing calcium carbonate. This coating is very hard and crystalline in character. An acid bath is the most effective method of cleaning. To remedy the condition, the high-service pumps may be arranged to take suction from the filter effluent instead of the influent. When the water passes through the filter before it reaches the pump, it has become more stabilized and little further trouble is experienced with incrustation. Vitreous phosphate applied to the suction of the pump will also prevent incrustation of the pump by calcium carbonate.

A wash water tank is usually lacking in the small plant. Sometimes a pump is provided, but very often the wash water is drawn from the main discharge of the plant to the distribution system. This is practical if there is an elevated tank on the system and if the filters require only a relatively small amount of wash water. At one plant, with a 6-in. force main about two miles long, the single filter was divided into two parts for washing purposes, so that enough wash water would be available from the small force main with its high friction loss. It is desirable that a gate valve regulating the rate of filter wash should be placed on the main wash water line so that wash water valves on each filter can be opened wide.

Clear wells have been omitted in some small plants in order to reduce the cost. Pumps take suction directly from the gravity filter effluent line and discharge into the distribution system. An elevated tank usually floats on the system, but sometimes a pump with automatic controls discharges into a hydropneumatic tank. The pump is in frequent operation during certain parts of the day. At some plants, the pumps will start as often as once a minute, operating for from 10 to 15 seconds at a time. Treating water under these conditions certainly presents problems which the large plant operator never encounters. Automatic equipment, actuating low-service pumps, chemical feeders, filters and the like, makes it possible to operate a plant of this type.

Operating Problems

Raw waters from impounding reservoirs often contain algae. For the most part, the small plant operator does not determine what organisms are involved but employs copper sulfate in varying amounts at different locations. Usually

the copper sulfate is applied on more or less of a schedule, such as once or twice a month. If the conditions are not improved, a supervising chemist may be called upon to advise a treatment.

The aeration of well waters is frequently accomplished adjacent to the filter building. Spray from the aerator saturates a brick building wall and the chemicals stored inside near the wall will take up so much moisture that it becomes impossible to feed them with a dry feeder. A separation of the aerator from the building is indicated.

Mixing devices at some softening plants require a great deal of maintenance because the small plants operate intermittently. Sludge collects on the bottom of the basin during the period of shutdown and makes it difficult to start the mechanism, with breakage often resulting.

The operation of filters in the plain filtration plant is largely a matter of keeping the filter material clean and free from mudballs. In the lime softening plant, the problem of maintaining filters is much more serious. The sand becomes heavily encrusted and at times cements together, forming large balls and slabs. The operator must be continually on the watch to prevent this condition. The filters should be prodded with a long-handled rake each time they are washed, so that the operator may know the condition of the sand. Frequent removal of sand from the surface of the filter is necessary to keep the sand level at a point below the bottom of the wash water troughs. When sand is heavily encrusted, little or no sand expansion takes place during the washing operation. The effective size of the surface sand often reaches 2 mm. or more. Below the surface the size is much smaller.

In washing purification plant filters, the operator must learn to work the wash water valve slowly. Valves in small plants are usually manually controlled and often cannot be opened too rapidly, but many are opened fast enough to upset the gravel layer. The carborundum-plate filter bottom which is coming into use should prevent troubles resulting from displaced gravel layers.

Tastes and odors are attacked in the small plant in about the same manner as in the large one. The operator of a small plant does not have the facilities for making threshold odor tests. Neither does he usually have the training to test for free residual chlorine. Activated carbon and combined chlorine are usually employed for taste and odor control. Free residual chlorination is used for taste removal at a few small plants where the operator is able to control it.

Disinfection at the small plant is usually best accomplished with hypochlorite rather than with liquid chlorine, because the former is more economical as well as being more simple in operation.

The maintenance of the plant in a neat condition is more of a small than a large plant problem, as the small plant often has no space for storage and becomes cluttered up with all sorts of equipment. In building small water works plants provision must be made for chemical storage, tool and meter room, and general storage space if anything approaching neatness is to be attained.

A small amount of effort toward landscaping the works will greatly improve its appearance. The planting of trees and shrubs can be done with no outlay of money because individual citizens or the garden club can be depended

on for material if the water works man indicates an interest.

Personnel Problems

In the small plant the water works income is often so restricted that the salary which can be paid to the operator is insufficient for full-time employment at the water treatment plant. Usually, in addition to operating the purification plant, he looks after the pumps and the distribution system, makes taps, reads the meters, sends out the bills and collects the revenue. He frequently ekes out a living by acting as town marshal, driving the school bus, running a motion picture theater or acting as janitor of the school. Such versatile men are operating some of the small plants.

These operators, who make regular daily coliform, alkalinity, pH and hardness tests, generally had no formal education beyond high school. Many have had none beyond the eighth grade. They have acquired their technical knowledge from men who have been employed to supervise the works and from the study of books and publications. On the other hand, many small plant operators are satisfied to permit the supervising chemist to direct the plant operation and they carry out his orders. It is necessary at all plants treating surface waters that the operator be an intelligent man with some initiative, because it is not possible to operate such a plant by following orders issued once a week by a supervisor. At a softening plant using ground water, the problem is quite different. The supervisor adjusts the treatment for a given type of water with the reasonable assurance that it will remain of uniform quality, with no changes in treatment necessary before his next visit.

Some explanation should be made about the supervision of small plants as it is practiced in Ohio. Regulations of the State Health Dept. require that operators in responsible charge of water purification plants hold one of three grades of certificates issued by the Director of Health. Plants which treat surface waters must have a man in charge who holds either an *A* or *B* certificate, the class required being determined by the size of the plant and the character of the raw water supply. Small plants in which the operator does not have the necessary qualifications for a *B* certificate must be supervised by a man holding such a certificate. The supervisor is then in responsible charge of the plant. How much instruction he gives the plant operator is really a matter between himself and the operator. Some operators are anxious to learn the technical phases of water purification, while others are satisfied to let the supervisor take responsibility for the plant's output. For the most part, however, the operators of small plants make an effort to improve their status by preparing themselves for the examinations which are held annually for the various certificates. This system of supervision of water plants has been in successful operation for more than 25 years in Ohio. The certification of plant operators, however, was begun only eleven years ago.

In an effort to improve filter plant operation, Ohio is following the lead of some other states in establishing a short school for small plant operators. Its first session, held in 1948 at Ohio State University, was largely devoted to elementary and basic training. No decision has been made as to the eventual schedule of training, but the purpose of the school is to raise the operators through training to a higher level of competence. It is hoped that the school may result in better trained personnel for small plants.

Operation of Water Works Gate Valves

By Donald M. Belcher

A paper presented on May 3, 1948, at the Annual Conference, Atlantic City, N.J., by Donald M. Belcher, Mgr., Hydraulic Div., Chapman Valve Mfg. Co., Indian Orchard, Mass.

MANY users of gate valves do not realize the magnitude of the forces that are required to operate these valves under ordinary conditions.

There are three customary ways of operating a gate valve—manually, hydraulically and electrically. Each method has its uses, depending on the size of the valve, the operating pressure, the required speed of operation and the convenience desired.

If a valve is operated with equal pressure on both sides of the disc—balanced pressure—the force required to operate it is small, amounting only to that necessary to move the disc and overcome friction. The operating effort, or spindle torque, required to open gate valves under balanced pressure is given by the formula:

$$T_s = \frac{KW}{12}$$

in which T_s is the spindle torque, in foot-pounds; K is the friction factor (at $f = 0.3$); and W is the dead weight of the moving parts, in pounds. The spindle torque for various sizes of valves is shown in Fig. 1. These data are for inside-screw valves without ball bearings. If ball bearings are employed, the operating effort will be cut approximately in half.

There is seldom occasion, however, to operate a valve under balanced pressure. The reason a gate valve is placed in a pipeline is to stop the flow of water through the line. Therefore, when the valve is operated, the pressure on one side will be greater than that on the other side—unbalanced pressure—and more force will be needed to operate the valve. To open a gate valve under unbalanced pressure involves not only the weight of the moving parts, but also the friction between the seats. The spindle torque formula for gate valves under unbalanced pressure is:

$$T_s = \frac{P(A_s + 0.3A)K}{12}$$

in which T_s is the spindle torque, in foot-pounds; P is the unbalanced pressure, in pounds per square inch; A_s is the spindle cross-section area, in square inches; A is the valve disc area, in square inches; and K is the friction factor (at $f = 0.3$). Figure 2 shows the spindle torque for various pressures and valve sizes. As in Fig. 1, the use of ball bearings would approximately halve the effort required. In closing a gate valve under the same conditions, the required forces are only slightly less than the forces necessary to open it, because the friction load is so predominant.

Manual Operation

If a valve is to be hydraulically or electrically operated, it is expected and specified that the operating equipment shall be of sufficient power to open or

close the valve under the actual unbalanced pressure to be encountered. Specifications for such operation are always definite, but, when a valve is to be manually operated, this requirement is seldom specified. The usual valve specifications will state only that valves 16 or 18 in. and above shall be equipped with gears. The A.W.W.A. specifications (1) and the regular manufacturers' standards call for gear ratios of 2:1 for valves 16–20 in., inclusive; 3:1 ratios for valves 24–36 in., inclusive; and 4:1 for valves 42–48 in., inclusive.

The absurdity of expecting to operate a valve by a reasonable manual effort under substantial unbalanced pressures, aided only by such gear ratios, can be readily determined by examining Fig. 2, which shows the forces to be overcome. It may be argued that the valves are generally furnished with by-passes and are therefore easier to operate, but the usual purpose of a by-pass is to fill the pipeline downstream from the closed valve in order to balance the pressure. If there is a considerable flow through the line, against which a valve has to be closed, a by-pass will be of little benefit.

One of the principal reasons for installing a valve in a distribution line is to provide a means of closing off the line if a break occurs below the valve. Under such circumstances, the valve may be subjected to full unbalanced pressure, and it is essential that the operating mechanism—whether manual, hydraulic or electric—be of sufficient power to close the valve, and to close it without loss of time.

It is evident that this would be impossible with the conventional type of manually operated valve, because the gear ratios listed above are not adequate. For instance, to close a 36-in. gate valve because of a break in a line carrying 80 psi. pressure—a common installation in distribution mains—would require an operating force of approximately 2700 ft.-lb. applied to the stem. Under these conditions, to close a valve equipped with the usual 3:1 gears, 900 lb. must be applied to a 12-in. wrench on the pinion gear. Assuming

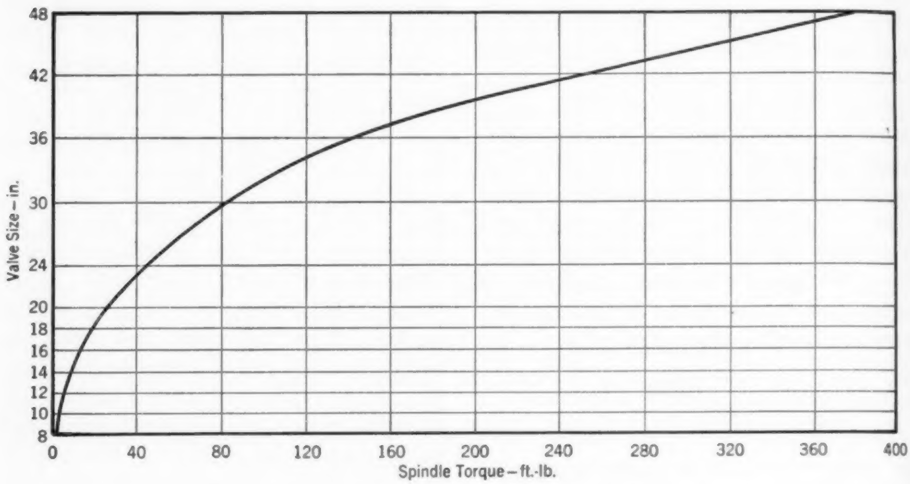

Fig. 1. Operating Effort Under Balanced Pressure

that one man normally pulls 40 lb. in operating a valve, five or six men would be required, even if a 4-ft. wrench were used. Much damage has resulted from broken mains when it was impossible to close the guardian gate valve quickly or entirely.

It seems incredible that engineers do not recognize this condition and demand adequate mechanisms for manually operated valves as they do for the electric or hydraulic types, especially when such mechanisms are available at a reasonable expense.

read: "Gearing shall be designed for maximum facility and speed of operation with a minimum number of men." This is an extremely indefinite requirement, and it is difficult to say how and by whom an interpretation could be made of the terms "maximum facility," "maximum speed" and "minimum number of men."

Specifications for sluice gates, which are used under the same general operating conditions as gate valves, always state that manual operating stands shall be of sufficient power to allow the

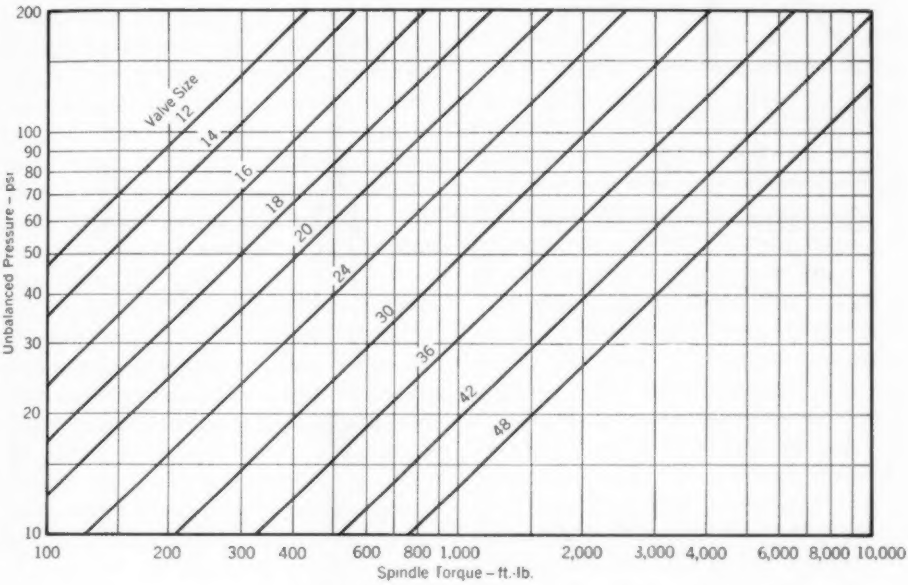

FIG. 2. Operating Effort Under Unbalanced Pressure

The A.W.W.A. specifications are considered standard for iron-body bronze-mounted valves for water works service, yet they pay very little attention to securing proper manual operating mechanisms for these valves. These specifications do not *require* any gears on any size valve but leave it to so-called supplementary gear specifications. Sections 21.2 and 22.2 of the A.W.W.A. specifications (1) both

operation of the gates, under full unbalanced pressure, by one or—at the most—two men, each pulling not over 40 lb. on a 12-in. crank.

There are several mechanisms available for operating a gate valve manually which are suited to the size of the valve and the unbalanced operating pressure:

1. Operating nut or handwheel attached to valve stem

2. Bevel or spur gears—open type without ball bearings—with ratios as previously shown

3. Bevel or spur gears, enclosed in a grease case without ball bearings, with ratios as previously shown

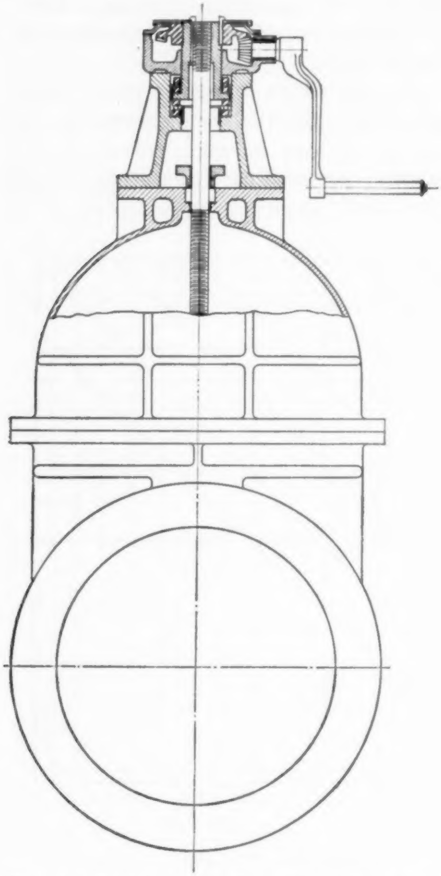

FIG. 3. Ball-Bearing Operating Head on Inside-Screw Valve

4. Geared ball-bearing operating head.

It has been standard practice for many years to furnish the first three mechanisms listed above, but they often require several men with extended wrenches to operate the valve under actual working conditions. Also available on the market are operating heads equipped with ball bearings and bevel, spur or worm gears having ratios as high as may be necessary to meet the operating conditions. Those of the higher ratios have two speeds for

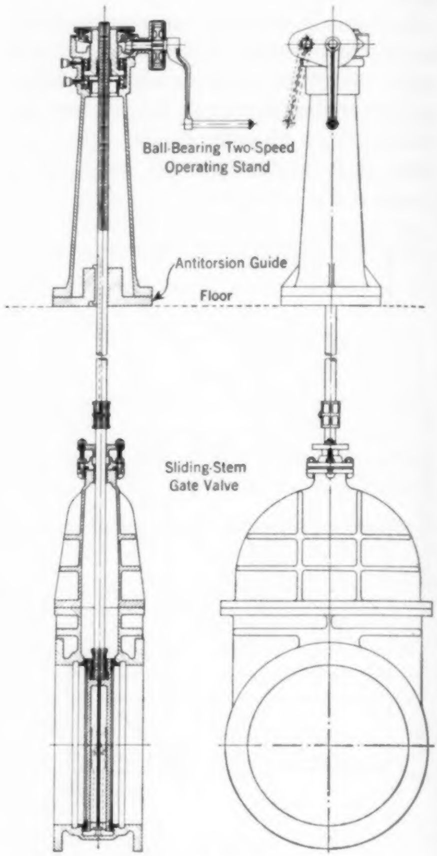

FIG. 4. Sliding-Stem Valve With Rising Extension Stem

quicker operation and are sufficiently powerful for one- or two-man operation. They can be applied to a gate valve as simply as ordinary enclosed gears (*see* Fig. 3).

The suitability of any of the above mechanisms for the required conditions can be determined from Fig. 2. It will

be recalled that the operating forces shown in Fig. 2 are those resulting from the use of plain bearings. If ball bearings are used, the operating effort is, approximately, only one-half of that shown.

When, as often happens, it is necessary or desirable to operate a gate valve from a location above it, an extension stem connects the valve to an operating stand on the floor above. For smaller valves—say, 14 in. and below—under ordinary operating conditions, it may be satisfactory to use a standard inside-screw gate valve with a nonrising extension stem and an indicator floorstand. However, the force required to operate larger valves under a substantial unbalanced pressure usually necessitates a sliding-stem type of valve with a rising extension stem. This is carried up to a stand equipped with the necessary gearing and ball races to allow easy operation by one man (*see* Fig. 4).

This type of installation has several advantages: (1) the thrust of operation (including the weight of the extension stem and the valve discs) is taken by the ball bearings in the operating stand, which reduces, by approximately one-half, the operating force required; (2) the threaded section of the stem is out of the water and is accessible for lubrication; (3) the sliding stem is not subjected to torsional strains during operation if an antitorsion device is supplied (desirable when the stem exceeds 15 or 20 ft. in length). There is no way to relieve torsion in a nonrising extension stem and it may be serious in a long stem.

It would seem a logical conclusion that sufficient use has not been made of ball bearings and higher gear ratios in the mechanisms being supplied for manually operated gate valves. It is therefore suggested that a clause should be included in specifications covering such mechanisms to insure that the manual operation will have sufficient power to meet the operating conditions. This clause might read:

"The valve shall be equipped with a manual operating mechanism of sufficient power to open or close the valve either under balanced pressure or under an unbalanced pressure of —lb. with a pull of not over 40 lb. on a 12-in. crank."

Hydraulic Operation

One of the most satisfactory means of operating a gate valve nonmanually is a hydraulic cylinder mounted either on the valve bonnet or on a floor above the valve. Such operation is simple, effective and reliable, and can be controlled from any convenient location. Although the cylinder is generally referred to as a hydraulic cylinder, it can be actuated by water, oil or air.

Selecting the proper size of cylinder for the conditions is entirely different from choosing a manual operating mechanism. Specifications for hydraulically operated gate valves always give the actual operating pressure in the valve and the pressure available for operating the cylinder. Consequently, a cylinder can be provided which will be capable of opening or closing the valve under the full unbalanced pressure. The size of the cylinder is determined by the relation between the actual unbalanced pressure in the valve and the minimum pressure available for operating the cylinder, taking into consideration the stuffing-box and piston-packing friction.

The cylinder may be of the cast-iron brass-lined type or of the brass tube type. The latter is satisfactory in sizes 12 in. or less when the operating pres-

sure in the cylinder does not exceed 100 lb. The cast-iron brass-lined type should be used for sizes above 12 in. or when the cylinder pressure exceeds 100 lb. There seems to be no decided advantage in using a cast-iron brass-lined cylinder in sizes smaller than 12 in. unless the operating pressure exceeds 100 lb., because the brass tube variety, if properly manufactured, is efficient and long lived and costs only about one-half as much.

Electric Operation

All that has been said in this paper about the satisfactory operation of gate valves by hydraulic cylinders applies equally to electric operation. Just as for hydraulic operation, the motor unit is always specified to be of sufficient power to open or close the valve under actual operating conditions.

There are two theories of motor operation: the motor may be stopped by a mechanically actuated limit switch which cuts off the current when the valve has been properly seated; or the torque principle may be used, the valve disc being forced into its seat and the motor stopped when the closing force exerted has built up to a predetermined amount.

Advantages are claimed for each of these methods of operation. According to the advocates of the travel-limit switch principle:

1. The range of motors available for such operation is so great that a motor of the proper size can be selected which will always have sufficient torque to operate the valve under the worst unbalanced pressure conditions.
2. Because of the careful control of the design factors of the valve parts and the motor unit equipment, the motor can be stalled by an obstruction in the valve without injuring any of the valve or operating mechanism parts or the motor itself.
3. The motor is stopped before the valve disc is excessively jammed into its seat, thereby reducing the wearing of the valve seat to a minimum.
4. The operation is not affected by widely varying pressures which cause varying torque loads.

The advocates of the torque principle claim:

1. The torque or pressure switch insures a tight valve closure without undue strain on the valve parts.
2. The torque switch provides protection from damage to valve parts by a foreign object obstructing the closing of the valve.

Reference

1. Standard Specifications for Gate Valves for Ordinary Water Works Service—7F.1—1939. Am. Water Works Assn., New York (1939); Jour. A.W.W.A., 31:502 (March 1939).

Removal of Hydrogen Sulfide From Well Water

By Sheppard T. Powell and L. G. von Lossberg

A paper presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., by Sheppard T. Powell, Cons. Chem. Engr., Baltimore, Md., and L. G. von Lossberg, Eng. Asst., Baltimore, Md.

ALTHOUGH sulfides are occasionally found in surface water, as a result of the deterioration of organic compounds or from miscellaneous pollution, these compounds occur most commonly in well waters. Because of their offensive odor, corrosive nature and other objectionable characteristics, it is highly desirable to remove them from water which is used for sanitary purposes, processing and cooling.

Greensand zeolites are damaged by the continuous application to the mineral of a water containing sulfide; as little as 2 ppm. of sulfide, expressed as H_2S, has been known to destroy such zeolitic material in a few months. Furthermore, many metals are rapidly attacked by relatively high concentrations of sulfides. Resistant alloys such as stainless steel and brass, which are effective in an oxidizing medium, are subject to aggressive attack by water containing sulfides, especially hydrogen sulfide. Because of the corrosive characteristics of water containing sulfide, the removal of this constituent is imperative if the rapid deterioration of equipment is to be avoided.

For many years it has been common practice to remove sulfides from well water by cascading the supply—that is, passing it over a coke tray aerator or using similar devices. The release of pressure and the exposure of a high-sulfide well water to the atmosphere are sufficient to remove a portion of the sulfur compounds, while the absorption of oxygen results in additional removal of the residual gas by oxidation. When the pH value is above 7.0, the sulfides are present as metallic salts which are removed by oxidation resulting from contact with the air. A large portion of the total sulfides is converted to free sulfur. If the sulfides are present in high concentrations, the deposition of sulfur may be voluminous, creating an objectionable condition. Where such reactions occur, aeration is generally practiced prior to filtration and the sulfur is subsequently removed by filtration.

Forced-draft aeration has been found more effective than natural-draft aeration or cascading, because of the scrubbing action and intimate contact of the air as it passes upward, by counterflow, through the water. There are, however, definite limits to the effectiveness of forced draft aeration, a fact which will be illustrated later.

It is well established that a reduction in pH increases the "release rate" of sulfides from water (1). Actually, the ionization constant is shifted, and, as a result of the new equilibrium, a larger percentage of the total sulfides is converted to hydrogen sulfide, which is more readily removed by aeration. This phenomenon has led to the use of mineral acids or carbon dioxide to re-

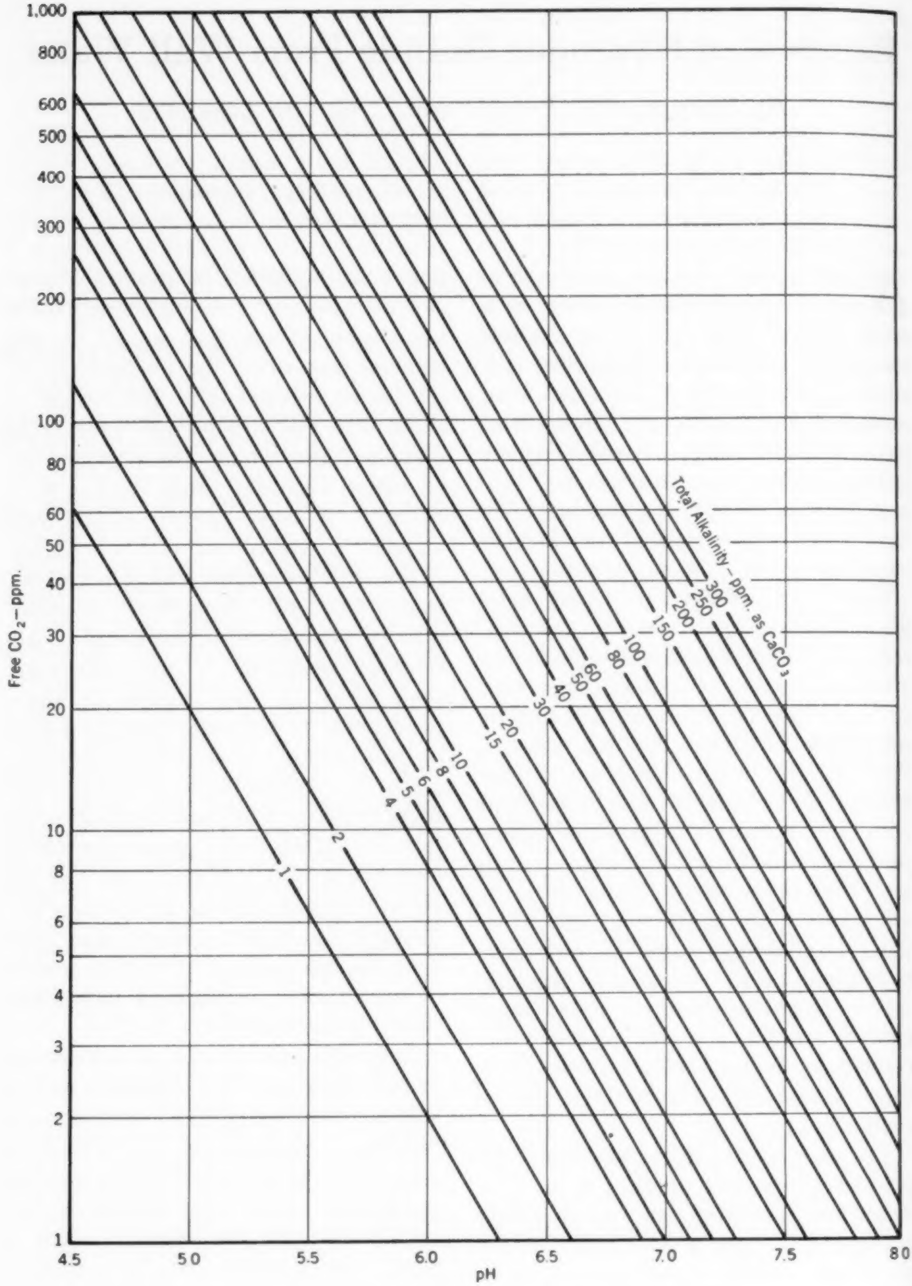

FIG. 1. Relation of Alkalinity and pH to Free CO_2

duce the pH prior to, or during, aeration.

Chlorine, when used in sufficient quantities, will oxidize the sulfides to sulfuric acid, but the high chlorine demand makes this treatment alone economically impractical because of the relatively large equipment and the cost of chlorine gas. Although these facts about the removal of hydrogen sulfide or total sulfides have been known for a long time, little definite engineering data are available for use in designing forced draft aerators to remove heavy concentrations of sulfides. The authors have recently assembled certain data on hydrogen sulfide removal which have been found helpful in the design of forced-draft aerators at a number of plants. These studies have not been as complete or exhaustive as might be desired and additional information will be required to establish ideal design data.

It is the purpose of this paper to present the information thus far compiled and to inspire the search for additional information to permit accurate predictions for effective apparatus under any given set of conditions. Numerous practical installations, based on extensive research and operating experience, have made it possible to design forced-draft aerators for the removal of carbon dioxide from water, but less informative data are available for sulfide removal.

Carbon Dioxide and Aeration

Approximately ten years ago, The Permutit Co. (2) experimented with the removal of hydrogen sulfide by a combination of carbon dioxide and aeration. Pilot plants were built to test this method. The work involved the use of synthetic flue gases and the assembly of test data which could be applied to the design of a full-scale plant using flue gases as the source of carbon dioxide. In the experimental studies, pure carbon dioxide from standard containers was mixed with air to assimilate the same concentration as that which would be contained in power plant stack gases; that is, approximately 13 per cent carbon dioxide by volume. The synthetic stack gas was introduced ahead of the aeration chamber in a single two-stage unit.

After considerable experiment, it was found that introducing the "stack gas" in the bottom of the carbonating chamber and the water in the top provided a counterflow of gas and water through the entire length of the compartment, resulted in maximum contact between the carbon dioxide and the water, effected pH reduction and removed hydrogen sulfide most efficiently. It was also learned that subsequent aeration in the second chamber served to reduce further the sulfide and remove the carbon dioxide. It was determined from these results that, for the well water tested, it was desirable to use about 1.5 cu.ft. of gas per gallon of water, which resulted in a reduction of the hydrogen sulfide below 0.5 ppm. Moreover, a tall tower was found superior to a short one as it permits longer contact.

The recent commercial designs for the use of stack gases and aeration to remove sulfides generally employ a forced-draft aerator, and the treatment is performed in two stages with two separate towers. The first tower is a combination contact, carbonating and scrubbing chamber to reduce the pH and remove the hydrogen sulfide, while the second tower provides for aeration and additional scrubbing to remove the carbon dioxide and, possibly, additional

sulfide. Generally, the second tower is operated as a forced-draft unit.

In the Permutit investigation, the water supply contained a hydrogen sulfide content of approximately 3.6 ppm. From the information secured in the pilot-plant studies made by the authors, it is believed that considerably more carbon dioxide or stack gases than estimated above would be required to secure comparable results for a supply having such a high sulfide content.

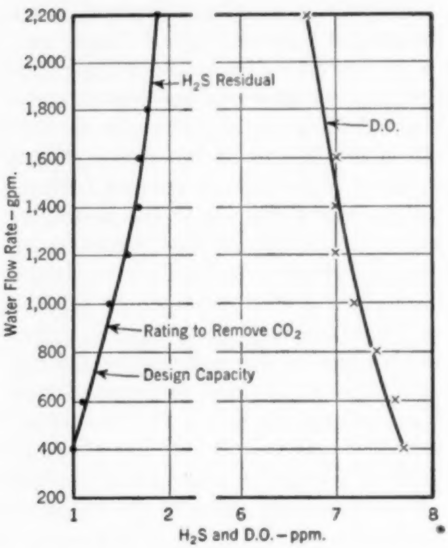

FIG. 2. Aeration and H_2S Removal by Forced-Draft Degasifier

Figure 1 shows the quantity of carbon dioxide required to reduce the pH of waters having different alkalinities. In the initial phase of the investigation using carbon dioxide, the pure gas was injected into the water prior to degasifying. As expected, the results were poor on account of the concentration of bicarbonate in the water. This condition resulted because of the demand for carbon dioxide to reduce the pH value of 4.5 to 5.0, which is excessive under such conditions. It was obvious, therefore, that a treatment based on the use of carbon dioxide injected directly into the supply ahead of the water was impractical.

Forced-Draft Aeration and Chlorination

Several years ago it was found that sufficient sulfide remained in a well water supply in the Jacksonville, Fla., area, subsequent to forced-draft aeration, to damage greensand zeolites

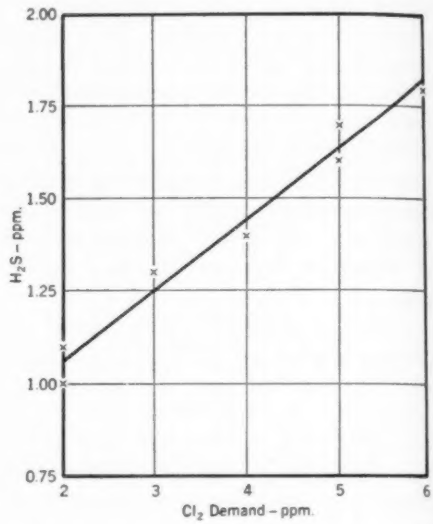

FIG. 3. H_2S Removal by Chlorination

within a few months (3). In fact, the mineral was so badly attacked that it had to be replaced, since it could not be treated and conditioned for future service. The raw water supply contained approximately 2 ppm. of hydrogen sulfide, and a commercial degasifier, based on the conventional design to remove carbon dioxide, was in service. The unit employed was 8 ft. in diameter and 16 ft. high, and the air was supplied at a rate of 3,000 cfm. against a pressure of 4 in. of water. Because of the inefficiency of the aerator for removing sulfides at

this flow rate, it was decided to reduce the flow through the unit and determine the economical point when using a combined treatment of forced-draft aeration and chlorination. Figure 2 illustrates the efficiency of the degasifier as varying volumes of water passed through the equipment.

The raw well water being treated had a pH of 7.8, a temperature of 54°F., a zero oxygen content and a 2.00-ppm. hydrogen sulfide content. It was, therefore, interesting to note during the tests the amount of dissolved oxygen picked up by the aeration of the water as well as the removal of hydrogen sulfide at different flows. Both of these curves are plotted on the graph.

In arriving at an economical combined aeration and chlorination treatment, the chlorine demand studies shown in Fig. 3 were made, based on a five-minute contact time and a pH of 7.8. These demands are somewhat lower than the ones found in subsequent studies (*see* Fig. 12, p. 1288). This is probably explained by the fact that the sulfide residuals were so low that the error in the accuracy of the test was large enough to account for the deviation from the theoretical demand.

Based on the costs of aeration, maintenance, operation and the like, an arbitrary design capacity of the forced-draft aerator for sulfide removal was found to be 750 gpm. This is 130 gpm. less than the design capacity for carbon dioxide removal. The blower capacity was increased, and it was decided that the rate should be 7.5 cfm. per gpm., or more than twice the 3.5 cfm. per gpm. estimated for carbon dioxide removal.

The data in Fig. 2 and 3 made it possible to prepare specifications for a commercial degasifier and chlorinator. The predicted results have, in general, been met and the plant is operating economically with reasonable efficiency. The combined treatment has been successful in completely removing the sulfides, so that damage to the zeolite has been eliminated.

Pilot-Plant Studies

A large plant recently built in the Midwest was so situated that it was desirable to use cold well water for heat-exchange purposes. The use of this well water, supplemented by cooling towers, made it possible to eliminate the installation of costly refrigerating equipment. Unfortunately, the well water contained as much as 30 ppm. of total sulfides, expressed as H_2S. Since the process required stainless steel and copper alloy heat-exchange equipment, and because the cooling water came directly in contact with the metals, it was imperative to remove the sulfides and convert the water from a reducing to an oxidizing supply, in which medium the alloys are resistant to corrosive attack.

Stack gases to provide pH reduction by carbon dioxide were not readily available in the quantities estimated as necessary to reduce the pH of the well water because of the appreciable alkalinity and the high sulfide content. An evaluation was made of forced-draft aeration alone and in combination with pH reduction by acid. In view of the damaging effect of very low concentrations of sulfide, it was planned to remove the constituent completely by chlorination subsequent to aeration. As previously indicated, the basic principles for providing a sulfide-free water are established; however, there were no engineering data on which to base the design of aerating and acid feed equipment. Therefore, pilot plant studies were made to secure these data.

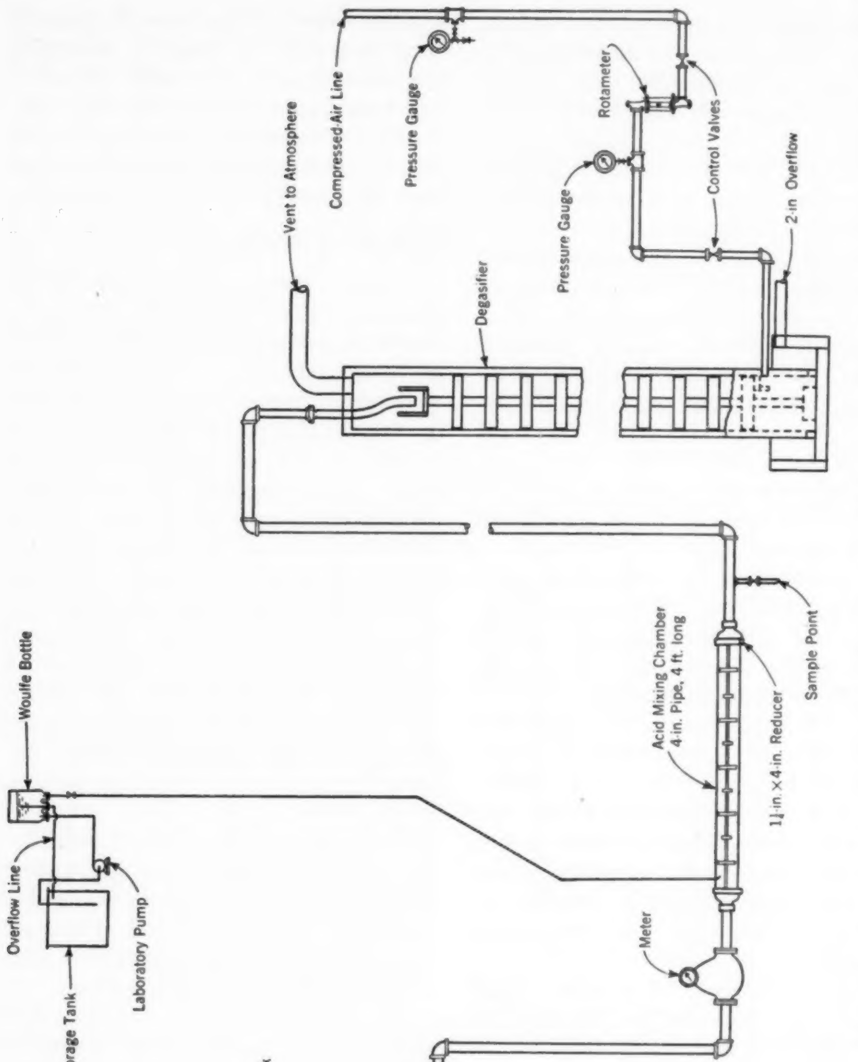

FIG. 4. Schematic Arrangement of Pilot Plant for H_2S Removal

Figure 4 is a schematic arrangement or flow sheet of the pilot plant and related equipment. The well was pumped at its full capacity (315 gpm.) to produce normal operating conditions. A slipstream, taken from the main well supply prior to the release of pressure, was delivered directly to the pilot-plant degasifier.

The air source for the tests was a 100-psi. compressed-air main available at the plant. The air flow was metered by means of a rotameter and the pressure was controlled by adjusting the valves shown. The equipment was quite flexible and gave excellent results. Back pressure in the degasifier was determined by installing a gage near the air influent of the unit, while the pressure across the rotameter was measured by means of a pressure gage and controlled by the valves shown in Fig. 4.

A new disk type of water meter provided the means for measuring the flow of raw well water to the aerator.

The acid feed which is shown in the figure was quite satisfactory for controlling a uniform rate of application of 10 per cent H_2SO_4 when it was desired to reduce the pH values. The equip-

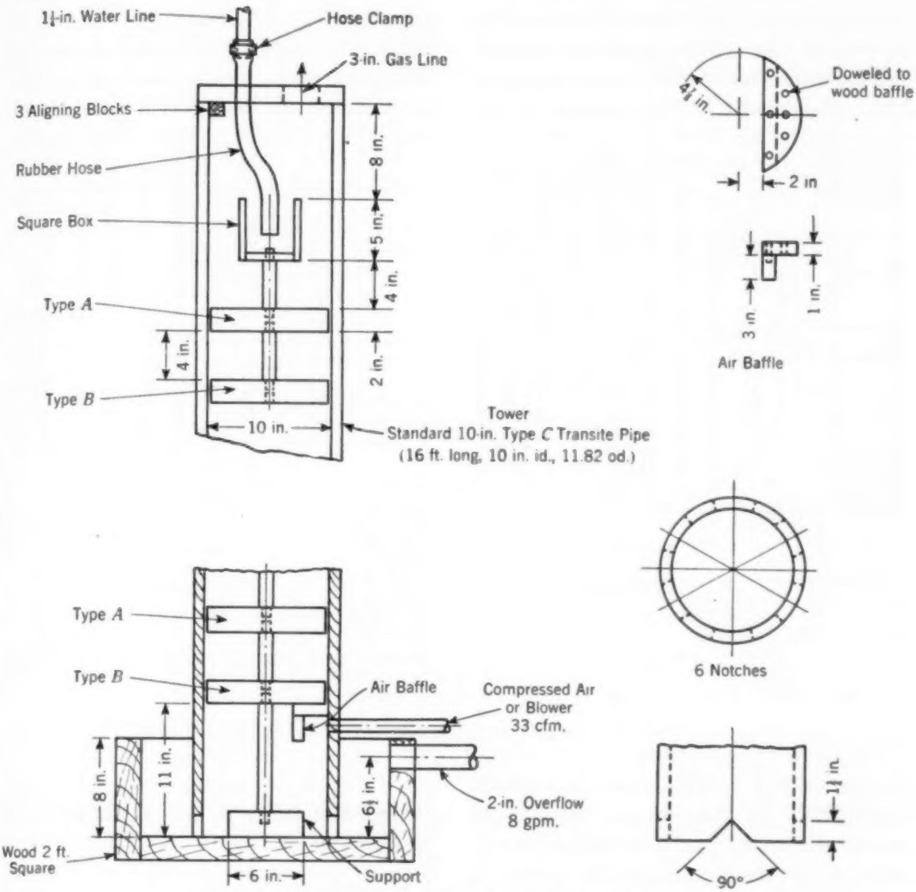

Fig. 5. Details of Experimental Equipment

Fig. 4. Schematic Arrangement of Pilot Plant for H_2S Removal

ment was made from laboratory apparatus which consisted of a small laboratory pump for recirculation, a Woulfe bottle and rubber and glass tubing.

A continuous sample from the effluent of the degasifier was taken at all times by siphoning water through rubber tubing from the collector box at the bottom of the unit into sample bottles.

Based on considerable experience, it has been found that the amount of hydrogen sulfide in the water is reduced appreciably by flashing as the supply leaves the main and discharges at atmospheric pressure. For this reason, a technique was developed which involves fixing the sulfide with acidified iodine as the sample is taken. This brings about immediate contact between the sulfide and the iodine and minimizes the sulfide loss. The excess iodine is titrated with thiosulfate; from the consumption of this chemical, by making a volume correction, the sulfide concentration, as H_2S, is determined. The details of this iodometric method are explained in the appendix to this paper (*see* p. 1289).

Figures 5 and 6 show the structural details of the experimental tray type of degasifying equipment. Studies conducted throughout the data collection period show that the well water had a pH of 7.7, an alkalinity (HCO_3) of 205 ppm., a hydrogen sulfide content of 17.8 ppm. and a temperature of 54.0°F. The average air temperature was 70°F., since the plant was constructed within a heated building in which the air lines were installed.

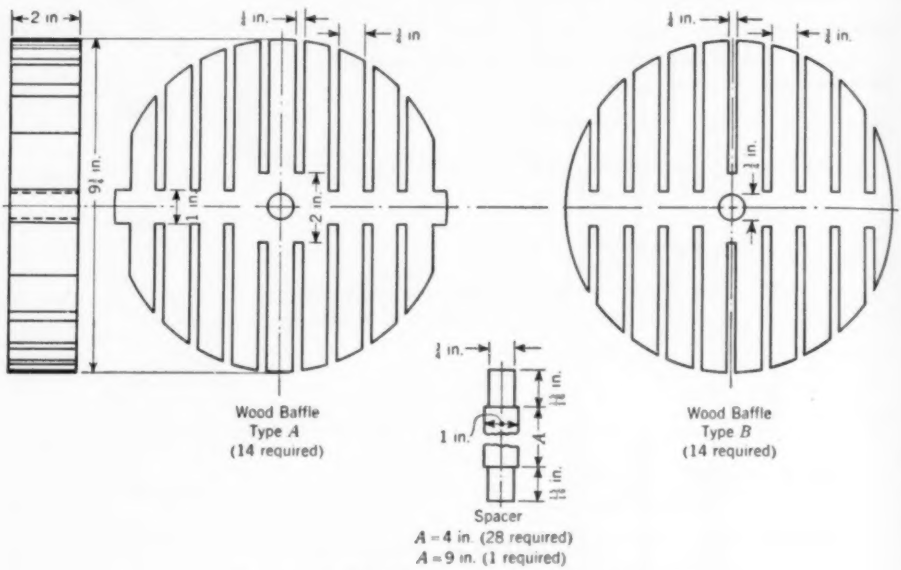

Fig. 6. Details of Experimental Equipment

Forced-Draft Aeration Only

Based on the favorable results secured in the Jacksonville area, the design data established there were used initially in the pilot plant studies—that is, 7.5 cfm. of air per gpm. of water, and 15 gpm. per square foot of cross-sectional area. The preliminary data from Florida also set the height of the degasifier at 16 ft. The pilot plant used

to experiment with the removal of sulfides by carbon dioxide had demonstrated the desirability of a tall degasifier. In like manner, the removal of dissolved carbon dioxide from water by aeration is facilitated by increasing the height of the forced-draft degasifier. A cylindrical tower was used in place of a square or rectangular unit to improve the distribution of fluids through this equipment. In a high degasifier, or aerator, of sufficient diameter, there is adequate vertical space and cross-

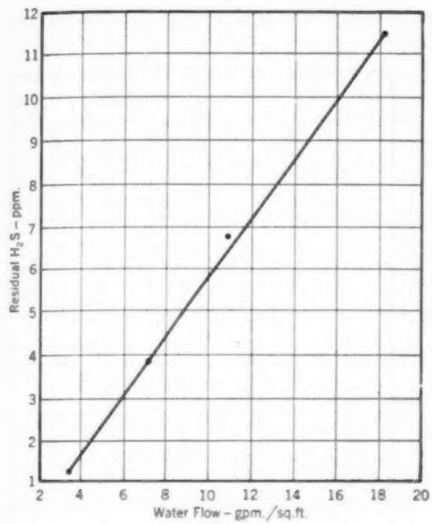

FIG. 7. H_2S Removal by Forced-Draft Aeration

sectional area through or over which the thin sheets of water can flow to permit the scrubbing air to contact the supply.

As Fig. 7 illustrates, the total sulfides, expressed as H_2S, can be reduced, without decreasing the pH, to almost 1 ppm.—provided the flow rates are sufficiently low—by forced-draft aeration in the type of degasifier used. This operation requires considerable cross-sectional area, thus necessitating extremely large apparatus. Furthermore, as previously mentioned, the free sulfur released is excessive. The conditions under which the data in Fig. 7 were obtained included a water temperature of approximately 54°F., an air temperature of approximately 70°F. and a constant air flow of 3,600 cu.ft. per hour.

It was originally believed that the air flow per unit of water was extremely important even at the normal pH value of the water (7.7). However, this was not found to be true, as indicated by Fig. 8. The conditions for these test data were: water flow, 14.65 gpm. per

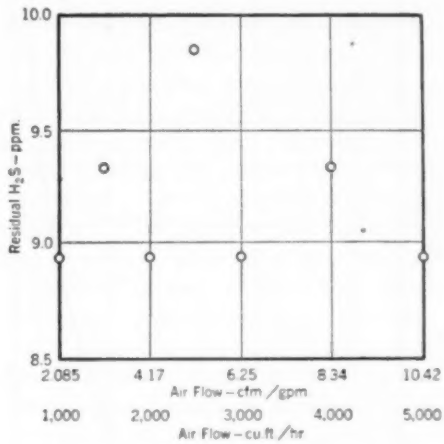

FIG. 8. Effect of Air Flow Rate

square foot; water temperature, 54°F.; air temperature, 70°F.; sulfide content of influent (expressed as H_2S), 17.8 ppm.; influent pH, 7.7; and effluent pH, 8.5. Beginning with an air flow of 2.085 cfm. per gpm. and increasing progressively to 10.42 cfm., it was noted that the total sulfide could not be reduced below 8.95 ppm.

During these tests, the water flow, in gallons per minute per square foot of area, was maintained constant, and, therefore, the air flow was the only variable. It is concluded from these results that, with the normal pH of the

well water (7.7), excessive air flows are not effective in reducing the sulfide residuals, provided the cross-sectional area is constant. This observation is in agreement with the theoretical hydrogen sulfide removal curve shown in Fig. 11, which indicates that the hydrogen sulfide removal is asymptotic to a pH of 7.0. The release figures on which the theoretical curve is based assume a scrubbing agent which is unreactive to the dissolved sulfides.

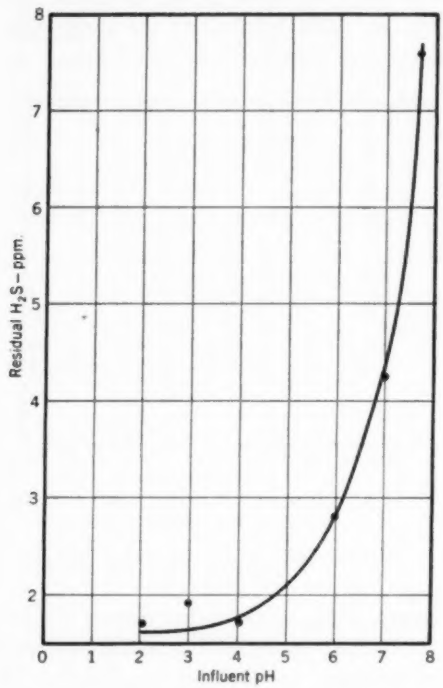

FIG. 9. Effectiveness of Reduced pH

In general, these tests relating air flow to water at a pH above 7.0 indicate that the removal follows a straight line and levels off at a residual of approximately 9 ppm. (expressed as H_2S) or a removal of about 8.8 ppm. hydrogen sulfide for all flows shown. A straight line was not indicated on Fig. 8 because of the varying position of the points; however, the scale is exaggerated and the greatest variation in the residual hydrogen sulfide is less than 2 ppm. By decreasing the scale, a straight line can be readily visualized. The variation in the residual tests can be laid to the experimental error. It is interesting to note that the pH value was increased from 7.7 to 8.6 by aeration only.

Combined pH Reduction and Aeration

Figure 9 shows the effectiveness of reducing the pH prior to forced-draft aeration. Here again, the air flow was held constant at 7.5 cfm. per gpm. and

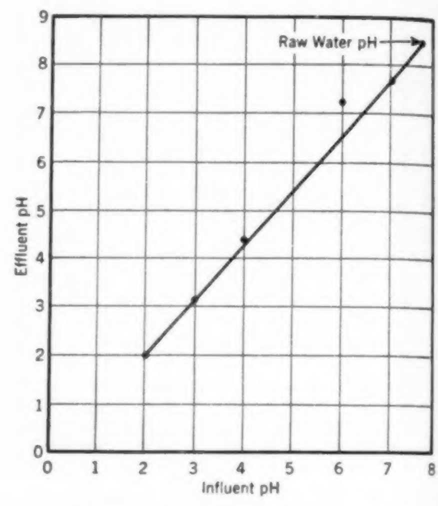

FIG. 10. Effect of Aeration on pH

the water flow was kept constant at 14.65 gpm. per square foot of area. (The approximate temperature of the air and water was, respectively, 70° and 54°F.) The influent pH was reduced progressively from 7.7 to 2.0. As Fig. 9 indicates, aeration only, without pH correction, reduced the sulfide in the raw water from 17.8 to approximately 8 ppm. Below this point, additional reduction was effected by lowering the pH value. The effective point for hydrogen sulfide removal is

between pH values of 4 and 5. Below this point it is apparent that appreciable reduction in pH to approach a zero residual of sulfides cannot be brought about readily. Again, it is interesting to note that the hydrogen sulfide cannot be reduced to zero by a combination of pH reduction and aeration, the residual sulfide at a pH of 2 being approximately 1.7 ppm.

The effect of aeration on the pH value is indicated in Fig. 10, based on

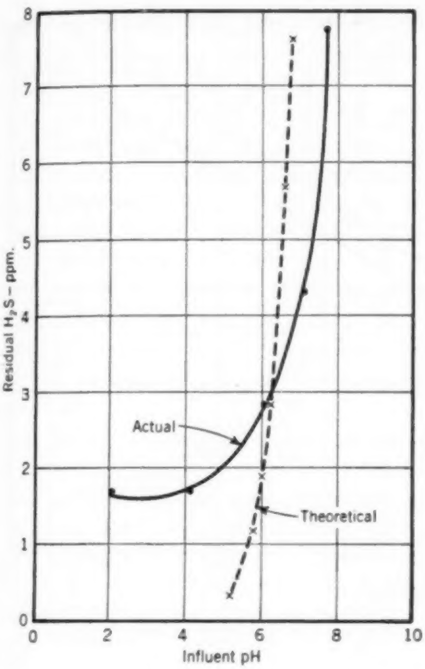

Fig. 11. Actual and Theoretical Results at Various pH Values

the same conditions as specified for Fig. 9. The effluent pH, by virtue of the removal of free carbon dioxide and hydrogen sulfide, is naturally raised. This is an important feature, since it illustrates the degree to which alkaline treatment is required to prevent the water from being extremely corrosive to steel piping subsequent to acid treatment and aeration.

It is readily appreciated that the pilot-plant studies followed to some extent the "release rates" of hydrogen sulfide at various pH values. As the ionization of total sulfides into hydrogen sulfide is increased with lower pH values, sulfide removal is facilitated. From the work of Pomeroy (1, 4, 5) the "release rates" for hydrogen sulfide were calculated and the predicted volume of sulfide that could be removed by aeration at different pH values was plotted (Fig. 11). On the same graph, the actual results obtained—which were previously shown in Fig. 9—have been plotted against the theoretical curve. Figure 11 thus illustrates the difference between the actual performance and the calculated results. For the purpose of calculation, the same sulfide concentration and corresponding pH values were assumed to secure points on the theoretical curve corresponding to the actual one. Although corrections in temperature were made, it is practically a negligible factor within the range covered.

It is interesting to note at this point that laboratory studies of the effect of vacuum de-aeration on sulfide removal show that, with a constant vacuum of 28 in. of mercury and with progressively lower pH values, the hydrogen sulfide removal tends to follow the type of theoretical curve in Fig. 11.

Chlorination

At the plant site, chlorine removal tests were not made, but such tests, using a five-minute contact time, were conducted in the laboratory with Baltimore city water having a pH of 7.8 and a temperature of 57°F. The results for removing sulfide residuals in a concentration of from 0.5 to 10.0 ppm. of hydrogen sulfide are shown in Fig. 12. It will be observed that the measured results are comparable to the theoreti-

cal. In fact, the discrepancy between the theoretical and actual results is probably due to a small experimental error. Here again, this error is exaggerated because of the relatively large scale. The theoretical curve plotted was based on the reaction:

$$4Cl_2 + 4H_2O + H_2S \rightarrow H_2SO_4 + 8HCl$$

In general, the chlorine consumption for the removal by oxidation of the hydrogen sulfide residuals is excessive. Therefore, it is important to reduce the sulfides to a value at which, taking all factors into consideration, it is economically justified to complete the removal by chlorination.

It has been forcibly demonstrated that concentrations of sulfides, expressed as H_2S, in the neighborhood of from 5 to 20 ppm. are extremely objectionable when this gas is discharged into the atmosphere as a result of aeration. Consequently, in the midwestern plant where these pilot studies were conducted, it is planned to inject the gas into the base of a 150-ft. stack so that it can be diffused and the nuisance value thereby reduced or completely eliminated.

Summary

1. Each plant requires individual study when considering the removal of sulfides from the well water supply. The controlling factors are raw water quality, plant capacity, design of equipment, predicted operation, process or other requirements and availability of stack gases or acid.

2. Aeration alone, when sufficient capacity is provided, can reduce the sulfides, even when present in appreciable concentrations, to below 3 ppm. However, the free sulfur released is objectionable.

3. To limit the size of a forced-draft aerator for removing sulfides, pH reduction is essential. pH reduction with

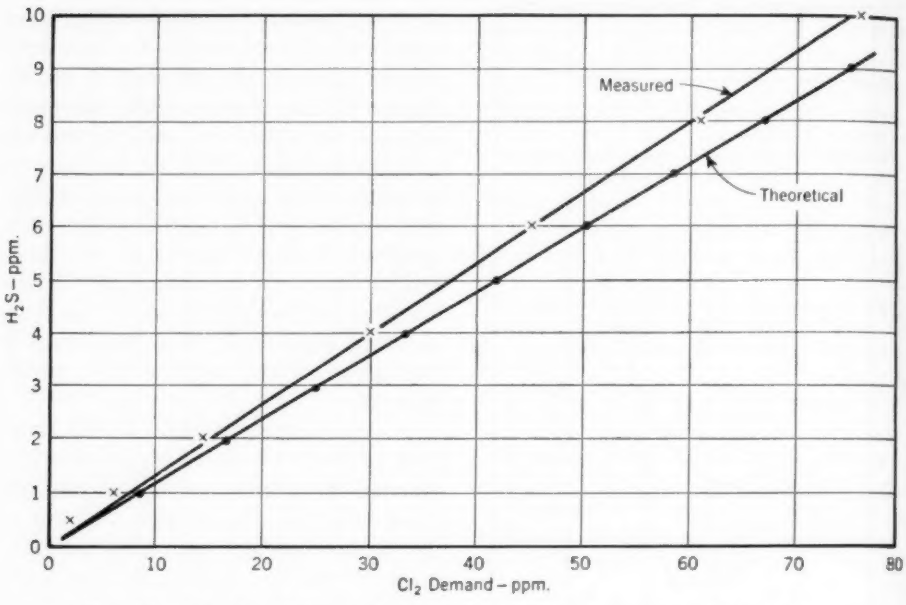

FIG. 12. Actual and Theoretical Results of H_2S Removal by Chlorination

acid provides positive control and will reduce the dimensions of the forced-draft aerating equipment to a fraction of the size required when the pH is 7 or above.

4. Excessive air flows at a pH of 7 will not result in appreciable reduction in the total sulfides if the cross-sectional area of the aerator is limited.

5. Aeration removes the sulfides not only by the scrubbing action but also by oxidation.

6. Forced-draft aeration combined with pH reduction is far more effective than cascading or natural-draft aeration.

7. Reducing the pH value with pure carbon dioxide gas injected into the water prior to aeration is not effective, especially when the alkalinity in the water is high. Furthermore, this method is far less efficient than adding the gas to the bottom of an aerator where the partial pressure of the carbon dioxide is maintained throughout the period of contact in the carbonation chamber.

8. When the equipment is properly designed, pH reduction with the use of carbon dioxide (flue gas), followed by aeration, has been found quite satisfactory if the total sulfides (expressed as H_2S) are in the range of from 3 to 4 ppm. It is believed that, with very high alkalinities and with high sulfide concentrations, this means for reducing the pH may not be satisfactory.

9. To effect sulfide removal by pH reduction, the pH value should be between 4 and 5 for optimum or most efficient results.

10. Sulfide removal with progressive reduction of pH values tends to follow the theoretical sulfide release data; that is, as the pH is reduced, more and more of the total sulfides are converted into hydrogen sulfide.

11. If it is desired to reduce the sulfides to zero, secondary chlorination is required, regardless of whether aeration alone or a combination of pH reduction and aeration is used.

12. The chlorine demand for the removal of hydrogen sulfide approximates the oxidation-reduction reaction.

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APPENDIX

Determination of H_2S or Fixed Sulfides in Water

The following method was used to test for sulfides:

Reagents and Apparatus

1. Sodium thiosulfate solution, $\frac{1}{40}N$ (other normalities can be used in accordance with the calculations given below, but unless the sulfides are high, stronger solutions will not be satisfactory)

2. Iodine solution, $\frac{1}{40}N$, approximately the same strength as the thiosulfate (need not be standardized)

3. Concentrated hydrochloric or acetic acid

4. Starch indicator solution

5. 10 ml. Mohr's pipette
6. Burette, 10 ml. or larger
7. Sampling bottles, 250 ml. or larger
8. Titration flask or casserole
9. Rubber tubing connected to source of sample with glass delivery tube approximately ¼ in. in diameter and 6–8 ft. long.

Procedure

Choose a sample volume depending on the quantity of sulfides expected—250 ml. for 0.8 ppm. hydrogen sulfide or higher, 500 ml. for less or 1,000 ml. for very small amounts.

Pipette 10 ml. of the iodine solution into the bottle and 1 ml. of acid (from a calibrated dropper). With the sample flowing, quickly insert the delivery tube to the bottom of the bottle and keep the end submerged while filling. Withdraw the tube just as the level reaches the neck, leaving room for the stopper. Small variations in volume will introduce negligible errors. If the brown color of the iodine fades out entirely, repeat with a smaller sample volume.

Stopper the bottle, mix, and take one or more additional samples to serve as checks.

Transfer the contents of a sample bottle to a casserole or flask, add starch, and titrate with thiosulfate until colorless. Record the titer as S.

Repeat with a distilled water sample free from reducing agents and record the titer as W.

Calculations

This procedure is based on the following equations:

$$H_2S + I_2 = 2HI + S$$

Equivalent weights:

$$Na_2S_2O_3 = Na_2S_2O_3 \cdot 5H_2O = \tfrac{1}{2}I_2 = \tfrac{1}{2}H_2S$$

Weights:

$$138.32 \qquad 248.32 \qquad\qquad 126.92 \quad 17.03$$

1 ml. N $Na_2S_2O_3$ = 17.03 mg. H_2S = 16.03 mg. S

From the above:

$$H_2S(\text{ppm.}) = \frac{(W - S) \times \text{Normality } Na_2S_2O_3 \times 17.03 \times 1{,}000}{\text{volume of sample used (ml.)}}$$

For $\frac{1}{40}$ N $Na_2S_2O_3$:

Sample Volume *ml.*	H_2S *ppm.*
250	1.703
500	0.851
1000	0.425

Characteristics and Cultivation of Sulfate-reducing Bacteria

By Robert L. Starkey

A paper presented on May 4, 1948, at the Annual Conference, Atlantic City, N.J., by Robert L. Starkey, Research Specialist in Microbiology, New Jersey Agricultural Experiment Station, and Prof. of Microbiology, Rutgers Univ., New Brunswick, N.J.*

THE diverse transformations of sulfur and sulfur compounds by micro-organisms can be divided into four groups:

1. Cleavage of sulfur from organic compounds
2. Oxidation of incompletely oxidized inorganic sulfur compounds, as well as elemental sulfur, with the ultimate formation of sulfate
3. Reduction of sulfate, partly oxidized inorganic sulfur compounds and elemental sulfur, with the ultimate formation of sulfide
4. Assimilation of sulfur from either sulfate or other inorganic or organic compounds of sulfur.

Many different micro-organisms are involved in these transformations (1).

Only a few of these numerous processes are brought about solely by a specific physiological group of bacteria which are vitally dependent on sulfur transformation for development. The sulfate-reducing bacteria belong to one of the select groups. As far as is known, these are the only bacteria that are able to effect the direct reduction of sulfate to sulfide. It is because of this reaction that they are included among the "nuisance organisms" in water. The sulfide not only makes the water unpalatable and odoriferous, but the bacteria may cause corrosion of the steel and cast iron of water distribution systems. It is probable, however, that sulfate-reducing bacteria are abnormal inhabitants of potable water supplies, for they generally require readily decomposable organic matter and anaerobic conditions. Consequently, strongly polluted water and sewage are more suitable substrates than potable water.

Distribution

Sulfate-reducing bacteria are widespread in nature. They are common inhabitants of soils but are more often encountered in ditches and in sediments of various bodies of water. They are abundant in canal mud, marine sediments and sewage and have been isolated from the water of artesian and dug wells, mineral waters, sea water, water from oil wells, stagnant water and bogs, and water in storage tanks. The water used to seal tanks containing gas or petroleum has been found to harbor these bacteria. In the sands and

* Journal Series Paper, New Jersey Agricultural Experiment Station, Rutgers Univ., Dept. of Microbiology.

clays overlying subterranean water deposits in Holland the bacteria have been found at a depth of 71 m. They have been recovered from the water taken from oil wells 1,000 to 2,000 m. deep.

Sulfate-reducing bacteria are particularly active in sediments of sea water and brackish water where conditions are anaerobic and where there are sufficient amounts of readily decomposable organic matter to support bacterial development. The bacteria are responsible for the large amounts of sulfide in the Black Sea and for most of the black iron sulfide commonly encountered in the sediments of tidal basins and the deep ocean.

Importance of Bacteria

Sulfate-reducing bacteria have been reported active in water cooling systems of industrial plants, where they produced sulfide that accumulated as iron sulfide in the corrosion products coating the pipes. They have also been associated with the corrosion of steel tanks holding petroleum and consumer gas. On occasion, the bacteria have proved troublesome in sand filters used to purify surface water. It was reported that they caused blackening of pulp in a paper mill. In certain large areas of sea water these bacteria have sometimes produced such great amounts of sulfide that the destruction of plankton, fish and birds has resulted. At times sulfide production has been so intense in both sea and fresh water as to cause blackening of lead paints of boats and buildings and fouling of the atmosphere. Sulfide produced by the bacteria in sewage has indirectly resulted in the corrosion of the concrete pipes through which the sewage passed.

During recent years attention has been focused on the relationship of these bacteria to the corrosion of metals (2). It has been reported that they provoke a severe type of corrosion under anaerobic soil conditions which leads to the pitting of steel and the graphitization of cast iron. Laboratory studies carried out in the last few years indicate that the bacteria are concerned in a similar type of corrosion in sea water and marine sediments. There is little evidence of their importance in the corrosion of the interior of water pipes. It seems likely, however, that the bacteria are associated with the corrosion of pipe surfaces partly coated with corrosion products and fouling material.

Bacterial Characteristics

Knowledge of the physiological and morphological characteristics of the bacteria can be used in developing methods for their isolation and identification. As already stated, these bacteria are strict anaerobes. Physiologically they are unique in that they require sulfate or certain incompletely oxidized inorganic sulfur materials as their specific oxidizing agents, and they generally use organic material as a source of energy for development. The organic materials yield energy through their oxidation by sulfate which is reduced to sulfide. A typical reaction brought about by these bacteria is:

$$\underset{\text{Na lactate}}{2CH_3\cdot CHOH\cdot COONa} + MgSO_4 = \underset{\text{Na acetate}}{2CH_3\cdot COONa} + CO_2 + MgCO_3 + H_2S + H_2O \quad \ldots (1)$$

Various organic materials can be used by the bacteria in place of lactate. They use a variety of mono- and di-saccharides; salts of organic acids, includ-

ing fatty acids; and also alcohols and amino acids. It has even been claimed that some sulfate-reducing bacteria are able to oxidize certain petroleum hydrocarbons. Furthermore, at least certain strains of the bacteria can actually develop as autotrophs, using hydrogen as their source of energy in place of organic compounds and bringing about the reaction:

$$4H_2 + CaSO_4 = H_2S + Ca(OH)_2 + 2\,H_2O \quad \ldots (2)$$

When hydrogen is thus provided they can grow in media containing no organic matter. In such media, bicarbonate satisfies their carbon requirements.

The bacteria can use sulfite, thiosulfate and possibly elemental sulfur as substitutes for sulfate, the oxidizing agent. Only a few species of sulfate-reducing bacteria have been described, the most common being *Sporovibrio desulfuricans* which brings about the transformation of lactate cited above. Another species, *S. rübentschickii,* is able to oxidize acetate to carbon dioxide and water and, therefore, leaves no acetate residue on oxidation of lactate.

The bacteria develop at reactions from pH 5.5 to 8.5, or possibly at somewhat more alkaline reactions. Some strains grow best in media with low salt contents whereas others are typically marine organisms. Some strains are mesophilic and grow best from 25° to 40°C., while others are thermophilic and develop between 45° and 60°C.

Morphologically the bacteria are all alike, being curved rods. At times the cells have a spiral shape which led their discoverer Beijerinck in 1895 to describe the cultures under the name *Spirillum desulfuricans.* Subsequently,

TABLE 1

Sulfate-reducing Bacteria Culture Media

BEIJERINCK (3)

Substance	Amount
Ditch water	1,000 ml.
Na or K malate or lactate	0.05–0.1 g.
Asparagin or peptone	0.05–0.1 g.
K phosphate	0.1–0.2 g.
$CaSO_4 \cdot 2H_2O$ or $MgSO_4 \cdot 7H_2O$	0.5–2.0 g.
Na_2CO_3	1.0 g.
Mohr's salt	trace

VAN DELDEN (4)

Substance	Amount Medium 1	Amount Medium 2
Tap water	1,000.0 ml.	1,000.0 ml.
Na lactate	5.0 g.	2.5 g.
Asparagin	1.0 g.	
NH_4Cl		0.25 g.
K_2HPO_4	0.5 g.	0.25 g.
$MgSO_4 \cdot 7H_2O$	1.0 g.	1.0 g.
Ferrous sulfate	trace	

BAARS (5)

Substance	Amount
Tap water	1,000.0 ml.
Na lactate	3.5 g.
NH_4Cl	0.5 g.
K_2HPO_4	1.0 g.
$MgSO_4 \cdot 7H_2O$	2.0 g.
$CaSO_4$	1.0 g.
Mohr's salt	trace

STARKEY (6)

Substance	Amount
Tap water	1,000.0 ml.
Na lactate	3.5 g.
NH_4Cl	1.0 g.
K_2HPO_4	0.5 g.
$MgSO_4 \cdot 7H_2O$	2.0 g.
Na_2SO_4	0.5 g.
$CaCl_2 \cdot 2H_2O$	0.1 g.
Mohr's salt	trace

they have been included under the genera *Microspira, Vibrio, Desulfovibrio* and *Sporovibrio.* The last generic name was applied because under certain cultural conditions the bacteria produce spores. The sporulating cultures are tolerant to exceedingly high temperatures.

The development of the bacteria is characterized by the formation of sulfide. Consequently, sulfide can be detected in some abundance either in the water, soil or corrosion products of metal where they are growing. Although the presence of sulfide may suggest the existence and development of sulfate-reducing bacteria, the sulfide is merely indicative, for sulfate reduction is only one of many sources of sulfide. Verification of the presence of sulfate-reducing bacteria can be effected by cultural tests using selective media.

Bacterial Cultivation

Various media have been proposed for enrichment cultures and for the growth of pure cultures of sulfate-reducing bacteria. Some of the media used for enrichment cultures are shown in Table 1. Beijerinck, who first described the bacteria, used comparatively complex media with the nitrogen supplied as organic compounds. One of the media used by van Delden, a student of Beijerinck, was more effective as an enrichment medium because it was more selective. The only organic constituent of this medium was sodium lactate, which limited development to few bacteria other than those that were able to reduce sulfate. The principal contaminating bacteria associated with enrichment cultures of sulfate-reducing bacteria in this medium were certain coliform organisms that showed considerable tolerance to high concentrations of hydrogen sulfide. The medium used by the author is similar to Baars'. It is also similar to that used by van Delden except that all of the sulfate is supplied as soluble salts. When this medium is inoculated with material containing sulfate-reducing bacteria and incubated at 30°C. under anaerobic conditions, hydrogen sulfide may appear in a few days, and the reaction is generally concluded in one to three weeks. The medium becomes black from the formation of iron sulfide, and opalescence from the suspended cells occurs. Because there is no accumulation of gas from pure cultures of sulfate-reducing bacteria, gas formation indicates the presence of contaminants.

The sulfate-sulfur content of the medium, exclusive of that contained in Mohr's salt, is 480 ppm. Therefore, if there is complete reduction of sulfate to sulfide, this is the maximum amount that can be produced. The amount of sulfate-sulfur that can be reduced by *S. desulfuricans* through the oxidation of all of the lactate contained in the medium is 496 ppm. (*see* Reaction 1). Consequently, irrespective of the sulfate content of the medium, 496 ppm. would be the amount of sulfide-sulfur produced by this species of bacterium in the medium proposed. The amount of sulfide-sulfur that might be produced by *S. rübentschickii* in the same medium would be as high as 1,487 ppm. according to the reaction:

$$2CH_3 \cdot CHOH \cdot COONa + 3MgSO_4 = 2CO_2 + 3MgCO_3 + 3H_2S + 2H_2O + Na_2CO_3 \quad \ldots (3)$$

This organism oxidizes lactate completely to CO_2 and H_2O, whereas *S. desulfuricans* oxidizes lactate incompletely, leaving residual acetate.

The use of sulfate as the specific oxidizing agent and lactate as the only organic material in the medium is desired in order to make the substrate as specific as possible for sulfate-reducing bacteria. Although asparagin, peptone and other organic sources of nitrogen

may be readily utilized by the bacteria, these materials should be avoided in enrichment media because they favor the growth of various other bacteria.

As culture vessels, it has been found convenient to use 60-ml. glass-stoppered bottles which are entirely filled with the medium so as to exclude air. The following procedure is used in preparing the bottles of inoculated medium: The culture vessels are sterilized in a dry-heat sterilizer. A small crystal of Mohr's salt (5 to 10 mg.) is held by forceps and heated in a gas flame to sterilize it, after which it is added aseptically to the culture vessel. The bottle is about half filled with recently sterilized and cooled lactate medium, and then the inoculating water, slime or other material is added in appropriate amounts. The bottle is then completely filled with lactate medium, observing aseptic precautions, after which the stopper is put in place to exclude all air bubbles. Throughout the procedure, the stoppers are handled with sterile tongs. During incubation, a small beaker is placed over the top of each bottle, as partial protection against contamination. The cultures are incubated at 28° to 30°C.

Growth will generally appear within a few days if the cultures are active. The culture vessels are incubated for three weeks before being tested in routine procedures, and it is considered that if the cultures fail to grow in this period of time sulfate-reducing bacteria are either not abundant or are inactive. At the conclusion of the incubation period the cultures may be transferred to bottles of similar medium or used for isolation studies. Determinations are also made on the culture medium for sulfide content; if the amount of sulfide-sulfur is less than 50 ppm., sulfate reduction is considered to be insignificant. With active cultures of sulfate-reducing bacteria, the amounts of sulfide-sulfur vary from 150 to 450 ppm.

As microscopic observations of the enrichment cultures may show a variety of bacteria, it may not be easy to recognize the specific sulfate-reducing bacteria. Since the cells are small, high magnifications should be used. The vibrios are motile, and where motility is observed the cells are found to have the characteristic spiral movement of curved cells. The population of bacteria becomes simplified by repeated subculture, but one cannot depend on the dilution of the inoculum in preparing subcultures to obtain pure cultures. In routine tests, pure cultures are not needed to prove the presence of sulfate-reducing bacteria, since the reduction of a large portion of the sulfate to sulfide in the selective enrichment medium is adequate evidence. The only sulfur contained in the medium is sulfate, and, unless appreciable amounts of organic sulfur compounds are introduced with the inoculum, practically all of the sulfide must be the product of sulfate reduction.

In place of glass-stoppered bottles other culture vessels can be used. When test tubes are used for this purpose, the solution medium can be sealed at the top with sterile paraffin oil or similar material after being inoculated. Screw-cap bottles completely filled with the medium have also been used, but particular care must be taken to provide a tight seal so that there is no penetration of air.

It is often desirable to secure sulfate reduction in subcultures from the first enrichment cultures as evidence of the

development of the specific sulfate-reducing bacteria. This is particularly true when considerable amounts of inoculating material are used which may have provided sources of sulfur other than sulfate for sulfide production.

Various means are available for isolating pure cultures of sulfate-reducing bacteria. Cultures should be employed which have been carried through several successive enrichment transfers and have shown active sulfate reduction, and the cultures should be at a stage of active growth. The culture material can be streaked on lactate agar medium similar in composition to the medium previously mentioned, but a richer agar medium, having the composition shown in Table 2, is preferable. This is more favorable for the growth of sulfate-reducing bacteria but is less specific than the lactate medium. The streaked plates should be incubated under anaerobic conditions. The cultures produce small brown or golden colonies along the streaks and the medium becomes black from iron sulfide around the colonies. These colonies can be further tested for purity on additional streaked plates of the same medium incubated under similar conditions. Since the most common contaminants of the mesophilic cultures are coliform organisms, a reasonable test for purity is the absence of growth on streaked plates of nutrient agar incubated aerobically. The pure cultures can be cultivated in stoppered deep agar tubes of the peptone-dextrose agar, which are kept anaerobic in sealed tubes containing alkaline pyrogallol.

TABLE 2

Rich Agar Medium

Substance	Amount g.
Tap water	1,000.0
Peptone	5.0
Dextrose	10.0
$MgSO_4 \cdot 7H_2O$	1.5
Na_2SO_4	0.5
Mohr's salt	0.01
Agar	15.0

A preferable method of purification involves the use of tubes of cooled but fluid agar medium inoculated with enrichment culture material. After the latter has been dispersed through the medium, the agar is solidified by rapid cooling. Various media can be used, such as peptone-dextrose or lactate agar. The tubes can be sealed with sterile paraffin oil and incubated at 30°C. Colonies of the sulfate-reducing bacteria appear as black spots within the medium. Well-isolated colonies can be obtained from the agar by breaking the tubes, removing the agar, aseptically dissecting out the colonies and transferring them to deep tubes of newly prepared agar medium.

Instead of using test tubes as culture vessels for colony isolation, glass tubing may be used which is drawn out at one end, partly constricted near the other and plugged with cotton. After the tubes have been sterilized, the drawn-out tip is broken off aseptically and the tube is drawn full of agar medium in which the cells of the enrichment culture are dispersed at a suitable dilution. When the tube is filled with the medium, both ends are sealed in a flame and the sealed tube is incubated. The sulfate-reducing bacteria produce black colonies that can be isolated in the manner indicated for the test tube cultures. Pure cultures of the sulfate-reducing bacteria can be recognized by their curved cells, which sometimes appear as spirals.

Sulfide Production

Sulfate reduction is not the only means by which sulfide is produced by micro-organisms. In fact, many different kinds of bacteria, as well as various yeasts and filamentous fungi, can produce sulfide from organic and inorganic sulfur compounds. The production of sulfide from organic sulfur compounds is common to a large number of micro-organisms. One of the principal sources of this sulfide is the amino acid cystine which is contained in peptone and various other substances frequently used in complex media. As an indication of the variety of bacteria that are able to produce sulfide from cystine, the results of Tanner (7) may be noted. He tested 131 bacterial cultures, of which 104 produced sulfide from cystine.

Various inorganic sulfur compounds are also reduced to sulfide by many bacteria, as well as by some other micro-organisms. Sulfite, thiosulfate and elemental sulfur are comparatively readily reduced by various micro-organisms. Since this activity is not limited to a specific group of bacteria, the production of sulfide in media containing these compounds cannot serve as an indication of the presence of sulfate-reducing bacteria.

It has been reported that sulfide is produced from sulfate by various bacteria, including coliform organisms and certain thermophilic bacteria. According to data of Clark and Tanner (8), six to nine of 102 cultures of thermophilic bacteria produced sulfide from sulfates of potassium, sodium, calcium or ammonium. Sulfate was reduced to sulfide by relatively few cultures compared to the number which formed sulfide from sulfite, thiosulfate, sulfur and cystine. Clark and Tanner further stated: "From the results it appears that sulfates are not readily reduced to hydrogen sulfide by thermophilic bacteria under the conditions of this test. A few organisms seem to have this ability though they are the exception rather than the rule and the amount of H_2S produced was small." The explanation for the production of small amounts of sulfide from sulfate by various bacteria was made by Beijerinck many years ago. In 1904 he stated (9) that the direct reduction of sulfate to sulfide is exclusively limited to the specific group of vibrios which he characterized as sulfate-reducing bacteria. Small amounts of sulfide could, however, be produced by other bacteria through a process of "indirect reduction," which Beijerinck explained thus: Sulfate is assimilated by the cells of many bacteria during their growth, and the sulfur is converted to organic sulfur compounds in their protoplasm. After the death of some of these cells in the developing cultures, a portion of the sulfur contained in the organic compounds of the cells becomes released, and hydrogen sulfide is formed. The sulfide was therefore a product of the decomposition of organic sulfur compounds and not of the direct reduction of sulfate to sulfide. Sulfide is produced in this way by various bacteria, but, when it occurs, sulfide formation is weak and only a small portion of the sulfate contained in the medium is transformed.

Consequently, small amounts of sulfide may be produced in enrichment cultures even though no sulfate-reducing bacteria are present. This should not be confused with the process of direct sulfate reduction.

Conclusions

By the use of simple media that selectively favor the development of sulfate-reducing bacteria to the exclusion of other types, sulfate-reducing bacteria can be cultured from various materials, such as water, slimes, corrosion products, soils and marine sediments. An estimate of the relative abundance of the bacteria in the material being tested can be obtained by culturing a series of dilutions of the material in the culture medium.

As there are various reactions by which micro-organisms can produce sulfide, a highly selective medium should be used in testing for the occurrence of sulfate-reducing bacteria. This medium should contain sulfate as the exclusive source of sulfur. Media containing cystine or other organic sulfur compounds—or sulfite, thiosulfate or elemental sulfur—are of little or no value for detecting the occurrence of sulfate-reducing bacteria in materials harboring a mixed population of micro-organisms.

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Slime-forming Organisms

By F. B. Strandskov

A paper presented on May 4, 1948, at the Annual Conference, Atlantic City, N.J., by F. B. Strandskov, Bacteriologist, Research Dept., Wallace & Tiernan Co., Inc., Newark, N.J.

THE significance of water as a carrier of dangerous bacteria has long been recognized. In man's struggle for existence, it is only natural that he should be concerned chiefly with the water-borne micro-organisms that affect his health directly. Because of the large volume of drinking water used, this interest has centered principally on the organisms that cause intestinal disturbances when ingested and, consequently, are considered as being of intestinal origin. *Escherichia coli* are normally present in intestinal tracts of animals, including man, and their occurrence in water is used as an index of fecal contamination. Although this may not be an entirely satisfactory method, it has simplified the problem of routine bacteriological examination of water for sanitary purposes a good deal, as it would be almost impossible to determine whether or not all of the various intestinal pathogens were present in each sample of water.

Although it is desirable to keep the total bacterial count of drinking water as low as possible, it is not absolutely essential from a public health point of view that the water be completely sterilized. A large variety of nonpathogenic organisms carried by water are, however, of vital interest to the water bacteriologist and engineer because of their normal tendency to produce a material generally known as slime, capsules, or sheaths. Because of the adhesive properties of this material, it tends to accumulate on surfaces and can increase in volume either through further bacterial growth or other metabolic activity, or by collecting and holding other insoluble debris from the water supply. This condition can, of course, become very annoying to the producers and consumers because of tastes and odors imparted to the water, but it is more serious in such industrial processes as condenser systems, paper mills, food processing plants and numerous other places where large volumes of water are used.

Factors Involved

The production of slime is not a characteristic of any particular group of bacteria but is probably a normal function of all bacterial species in their smooth growth phase. Although there is a lack of information regarding the factors affecting capsule production by micro-organisms of industrial significance, the influence of temperature, nutrients and chemical and physical properties of the medium on some human pathogens has been studied. Morgan and Beckwith (1) have shown, for example, that capsule formation by members of the coliform-typhoid-Salmonella group is increased considerably

when the temperature of incubation is lowered to 10°–20°C. as opposed to 37°C. A readily fermentable carbohydrate was also required, but the structure of the carbohydrate used did not affect the antigenic structure of the capsule.

The effect of electrolytes on capsule formation by *Klebsiella pneumonia* was studied by Hoogerheide (2). Although a certain concentration of electrolytes is required for growth and capsule production, an excess was inhibitory to capsule production even though it did not affect the rate of growth of the organisms. The effectiveness of the electrolytes studied in inhibiting capsule formation followed the lyotropic series and is believed to be due to their physical adsorption on the cell surface or, more specifically, on the enzymes involved in the synthesis of the capsular material.

In addition to the direct influence of environmental conditions on capsule production by bacterial cells, it is also possible that environment may be selective for naturally occurring mutants capable of producing slime under conditions inhibitory to the parent strain.

Another factor that cannot be overlooked is the effect of other organisms in a mixed culture, such as is usually found in industrial slimes. It is entirely possible that some micro-organisms can grow and produce copious quantities of slime in an environment conditioned by other organisms but could not do so if present in pure culture.

Bacterial capsules are, in most species, essentially high-molecular-weight polysaccharides that consist of various combinations of sugars, aminosugars and sugar acids. Ivanovics (3), however, in a study of the capsular material of the anthrax bacillus and several strains of *Bacillus mesentericus*, found that it was a polypeptide made up largely of d(–) glutamic acid. Bovarnick (4) extended this study to *Bacillus subtilis* and found that this organism produced a polypeptide made up exclusively of d(–) glutamic acid, regardless of whether the organism was grown on a medium containing glutamic acid or peptone as the source of nitrogen. Recently Hanby and Rydon (5) have purified the capsular material of the anthrax bacillus further and found that it also is made up exclusively of d(–) glutamic acid. It is interesting to note that the organisms producing glutamic acid polypeptides are all aerobic gram-positive spore formers and that some are of the types often found to be responsible for industrial slimes.

This difference in capsular structure may be very significant since the chemical groupings are different, and their reactions with various disinfectants could influence the quantity required to give satisfactory control. The free chemically reactive groups in a polypeptide of glutamic acid are carboxyl and amino groups, while in the polysaccharides they are chiefly hydroxyl groups.

Bacterial Cultures

Although the majority of known bacteria can be cultured on nutrient agar or on agar enriched with certain plant or animal extracts, there are a number of autotrophic organisms such as the nitrifying bacteria—a common inhabitant of water—for which organic materials are very toxic, and these organisms can be grown only in inorganic solutions. That there are numerous bacteria of this type present in water supplies can be demonstrated by immersing a clean

glass slide in the water for several days, and, after removal, fixing and staining it for microscopic observation. Many forms are observed in this manner which do not grow readily on nutrient agar, although some of them may show up as almost microscopic colonies after several days of incubation. Occasionally the growth of some organisms on nutrient agar can be improved by using the water from which isolations are to be attempted in the preparation of the medium. This has been particularly valuable in the isolation of marine bacteria because of the specific salt requirements. Trace elements that are stimulatory to bacterial growth may also be present in the water.

In addition to the variation in nutritional requirements, the temperature requirements of bacteria for growth vary over a wide range. Some will grow at almost freezing temperatures, while others, such as the thermophiles, require temperatures as high as 55°–60°C. Because of the variation in nutritional and temperature requirements of bacteria occurring in water, it is obvious that, although numerous bacteria can be isolated and grown on artificial media in the laboratory, this is not proof that they are the predominating types or that they are capable of growing and producing troublesome quantities of slime in the system in which the water is to be used. Also, the water may appear to be almost completely sterile because the majority of the organisms present cannot be isolated by standard laboratory techniques but may, nevertheless, grow profusely and be very troublesome in industrial systems.

Although total bacterial counts of natural waters cannot be achieved on ordinary laboratory media, the counts obtained in this manner can be of value in checking the effectiveness of some active sterilizing agents such as chlorine when no significant difference in resistance exists in vegetative bacterial cells of various types. If those organisms originally present which could be cultured have been killed, it is reasonable to assume that all vegetative bacterial forms have been eliminated.

Identification of Bacteria

In the bacteriological examination of industrial slimes, it is again important to keep in mind that the conditions under which the bacteria are growing and producing slime are difficult to reproduce in the laboratory. It has been observed that the organisms isolated from these slimes on dextrose or nutrient agar do not necessarily correspond to those seen imbedded in capsules when a direct microscopic examination of the slime is made. Many varieties of bacteria usually adhere to the slime but are not actively engaged in the production of the material. They may, however, outgrow the causative organisms on laboratory media. This possibility is stressed by the findings of Malm (6), who isolated a large variety of molds and bacteria on laboratory media from paper mill slime but was unable to reproduce the original slime conditions with pure cultures of any of the organisms. It is felt, therefore, that the time and labor involved in making bacterial isolations and counts on laboratory media from industrial slimes are not justified by the information gained. With a great deal less effort one can obtain a much clearer picture by making direct microscopic observations of the materials.

The procedure used in the author's laboratory is as follows: A wet mount of the slime to be examined is prepared

and observed under low power for larger forms, such as algae and molds, which will be discussed later. Another wet mount is prepared, stained with Lugol's iodine solution and observed under a magnification of 430 diameters for the presence of filamentous iron bacteria. For the identification of other bacteria, two types of slides are prepared. A gram stain is made of a dried and fixed smear and observed under oil immersion with a magnification of about 930 diameters. In such a preparation there is usually a good deal of interfering debris present, but a trained technician can easily distinguish between stained bacteria and other stained materials. A variety of organisms may be observed, but one type usually predominates. The gram stain is important, particularly where attempts are made to use such compounds as organic mercurials, anionic or cationic wetting agents or substituted phenols to eliminate the slime. Appling and McCoy (7, 8) in a series of papers have shown that gram-negative organisms are uniformly more resistant to these types of compounds than are gram-positive organisms.

In addition to the gram stain, a capsule stain is made as a further aid in identifying the type of organism producing the capsular material. The method used in the author's laboratory is a negative stain in which a loopful of the material to be studied is mixed thoroughly with a drop of India ink on one end of a glass slide. After mixing, the edge of another slide is brought into contact with the drop and is drawn slowly across the slide, leaving a thin film which dries rapidly without heating. After the slide has dried, it is immersed in a 2.5 per cent alcoholic solution of safranin for one minute, washed in tap water, dried and observed in the same manner as the gram stain. By this process, the bacteria stain red, the capsular material appears as a clear area surrounding the bacterial cells, and the background is black. In addition to helping identify the causative organism, the capsule stain shows the thickness of the capsule surrounding the bacterial cells.

The size of the capsules surrounding the bacterial cell may affect the quantity of disinfectant required to kill the organism, because the physical and chemical demand of the capsular material for the disinfectant must be satisfied before it can attack the bacterial cell.

Algae and Molds

In addition to bacteria, algae and molds are often found to be involved in industrial slimes. The extent of algae infection of water can be determined by the Sedgwick-Rafter method, which involves the filtration of a large quantity of water through a layer of sand of a certain particle size. When filtration is complete, the sand is suspended in a small volume of water, and, after sufficient agitation to release the algae particles, a specially constructed counting chamber is filled and the algae particles are counted with the aid of proper magnification.

The concentration of algae particles in a water supply can also be accomplished by continuous centrifugation. After concentration, observations are made in the same manner as for the material obtained by sand filtration. The density of algae in water supplies arrived at by these methods can be used as an index of possible slime formation by these organisms in the systems in which the water is to be used, but

only if the conditions in such systems are optimum for algae growth.

The mold particle count of water could be obtained in the same manner, but the molds commonly occurring in water—*Rhizopus, Mucor, Alternaria, Penicillium* and *Aspergillus*—are relatively easy to cultivate in the laboratory on artificial media. They can be grown on a nutrient agar enriched with dextrose and adjusted to a pH level of 4.5–5.0. This low pH level is inhibitory to the growth of bacteria and thus eliminates interference by these organisms. One difficulty involved in making mold counts is that the molds have a tendency to spread rapidly over the entire plate and individual colonies are hard to recognize. This difficulty can be eliminated by making counts with the aid of a low-power microscope as soon as visible growth appears.

Identifying Molds and Algae

As mentioned in the discussion of the investigation of industrial slimes for bacteria, the presence of molds and algae can be detected in a wet mount by using a magnification of approximately 100 diameters. It is beyond the scope of this paper to discuss the morphological characteristics of the various genera upon which the classification of these organisms is based. Furthermore, there is, at least at present, little reason for believing that the algae responsible for industrial slimes vary significantly in their resistance to chemicals, and they can usually be inhibited by low concentrations of chlorine or copper salts.

The common saprophytic molds seen in industrial slimes differ somewhat in morphological characteristics. This is particularly true of their spores and spore-bearing bodies. The significance of these differences as a factor in resistance to disinfectants has not been established. The resistance of *Aspergillus niger,* one of the molds often encountered, to various organic mercurials, wetting agents and substituted phenols was studied by Appling and McCoy (8). They found that the mold was more resistant to these disinfectants than was the most resistant bacterium studied. In some instances the difference was only very slight, but in others the resistance of the molds was four to five times as great. Because of the lack of knowledge about the comparative resistance of the molds to the common disinfectants used in slime control, it does not appear essential to identify the exact genus represented. It may be well, however, to keep in mind that at least one of the common molds is more resistant to the slow-acting disinfectants than are gram-negative bacteria.

Summary

Micro-organisms can be very troublesome in industrial processes because of their ability to produce large quantities of slime. This is not a property of a few but probably of all micro-organisms when the environmental conditions are favorable. Such factors as temperature, nutrients and concentration of electrolytes affect this property in some organisms, and it is reasonable to expect, because of the similarity in the physiology of micro-organisms, that this will hold true for all micro-organisms.

The microbiological slime-producing potential of water supplies cannot be definitely determined by ordinary laboratory techniques because of the wide variation in nutritional and temperature requirements of micro-organisms. If a nonspecific sterilizing agent is being

used, the counts on nutrient agar before and after treatment are, however, indicative of the degree of sterilization.

In the investigation of industrial slimes, a clearer microbiological picture can be obtained by direct microscopic examination than by attempting to culture the material on laboratory media. If the responsible organisms are found to be bacteria, their gram reaction should be determined because of the difference in resistance of the two types to some disinfectants as well as the difference in the type of capsular material produced by the aerobic gram-positive spore formers that have been studied.

This information can be helpful in selecting the type and quantity of disinfectant to be used, although variations in such factors as pH, temperature and organic matter content, all of which affect the activity of disinfectants, make it impossible to state that a certain dose of any chemical will control the growth of any particular organism in all industrial systems.

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Bactericidal Properties of Free and Combined Available Chlorine

By C. T. Butterfield

A modified version of a paper appearing in Public Health Reports, Vol. 63, No. 29 (July 16, 1948), by C. T. Butterfield, Head Bacteriologist, Water and Sanitation Investigatiors, U.S. Public Health Service, Cincinnati, Ohio.

WHEN chlorine was first used for the disinfection of drinking water supplies, it was generally believed that some fixed amount of chlorine would sterilize all waters. Studies at that time were pointed toward the determination of this optimum dose. Later it became known that enough chlorine had to be added to satisfy the chlorine demand of the water and to provide a residual chlorine concentration which would insure disinfection. Interest then centered for a number of years on the determination of residual chlorine and of the standard chlorine residual which would insure proper disinfection of the water under any conditions. The bactericidal results obtained by using a standard residual chlorine were inconsistent and the disinfection was often unsatisfactory.

The development of the chlorine-ammonia and break-point processes for the prevention or destruction, or both, of tastes and odors led to a recognition of certain facts about the disinfection of water with chlorine:

1. Free available chlorine is a much more potent disinfecting agent than combined available chlorine.
2. The standard ortho-tolidine test does not differentiate between free and combined available chlorine residuals.
3. Both pH and temperature affect the bactericidal efficiency of free and combined available chlorine.
4. The habit of thinking of residual chlorine without differentiating between combined and free available chlorine was without doubt responsible for the inconsistencies in the results obtained, the differences of opinion and the failures to establish satisfactory standard residuals.

Prior to the development of adequate tests for the separate determination of free and combined available chlorine residuals, studies were made in the Public Health Service laboratory of the bactericidal properties of each of these forms under carefully controlled conditions, so that there could be no question about the purity of the active bactericidal agents. That is, tests were made with free available chlorine with all traces of combined available chlorine excluded, and in tests with combined available chlorine no free chlorine was present. These studies (1, 2) were made at pH values ranging from 6.5 to 10.7 and in two temperature ranges of 2° to 5° and 20° to 25°C. The bacteria used for the tests were not limited to coliform group organisms, *Escherichia coli* and *Aero-*

bacter aerogenes, but also included strains of *Pseudomonas pyocyaneae, Eberthella typhosa* and *Shigella dysenteriae.* The shigella or dysentery group, which might be considered the most important from a sanitation viewpoint, included a number of varieties of shiga, Flexner, Boyd 88 and sonnei strains.

In the following discussion these results are summarized with a view to making a practical application of the more important features. A comparison is made of the relative efficiency of free and combined available chlorine in water disinfection. Certain minimum standards, with the supporting data for the proposed safe residuals under the various conditions, are presented for consideration.

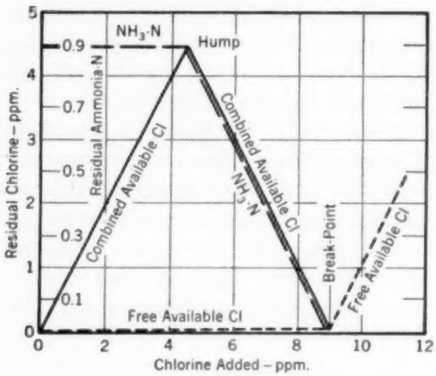


FIG. 1. Ideal Residual Chlorine Curve (Ammonia Solution)

Ideal Residual Curve

For the purpose of illustration, Fig. 1 shows an ideal diagrammatic residual chlorine curve in the presence of 0.9 ppm. of free ammonia, as nitrogen. With 0.9 ppm. of ammonia-nitrogen initially present, there is no change in the ammonia-nitrogen content until 4.5 ppm. of chlorine has been added (the ratio of chlorine to ammonia-nitrogen is approximately 5 : 1). Until the residual of combined available chlorine is at the maximum point (popularly called the "hump") the ortho-tolidine residual chlorine content is the same as the amount of chlorine added, and all of the residual chlorine is present as combined available chlorine.

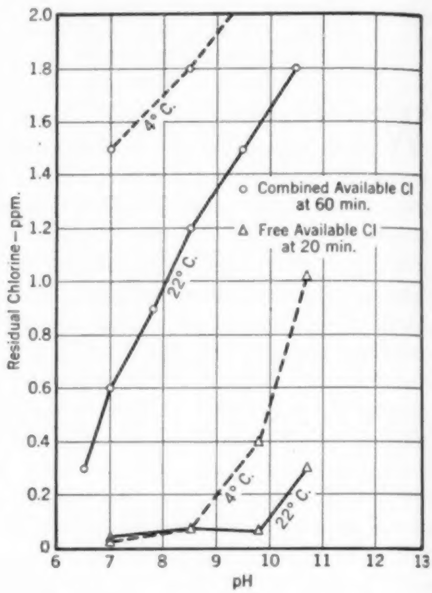


FIG. 2. Residual Requirements for 100 Per Cent Kill

After the hump has been reached, added amounts of chlorine result in corresponding decreases of ortho-tolidine residual chlorine and ammonia-nitrogen, until, when about 9.0 ppm. has been added, the residual chlorine content and the ammonia-nitrogen content will be zero (3). Within this part of the curve the residual chlorine present is combined available chlorine. Increments of chlorine beyond this zero point (referred to as the "break-

point") produce corresponding increases in residual chlorine, and this residual chlorine is free available chlorine.

The ideal curve in Fig. 1 therefore shows that, when the amount of added chlorine is exactly enough to achieve the zero point: (1) there is neither free nor combined available residual chlorine present; and (2) the water is entirely free of bactericidal properties. This would be true, in the illustration cited, even though 9.0 ppm. of chlorine was added to the water.

Although this exact end-point in the reaction is difficult to attain in practice, it has occurred in several tests which definitely showed that bactericidal action does not take place at this point. That post-break-point residual chlorine is free available chlorine may be demonstrated by the test procedure indicated or by any one of several others which have been developed by chemists.

Effect of Temperature

In Fig. 2, the influence of temperature on the bactericidal properties of free and combined available chlorine is illustrated, and the relative efficiency of the two is indicated. The points recorded for combined available chlorine are based on results obtained after 60 minutes of exposure at the temperature given, and the results for free available chlorine, after only 20 minutes of exposure. It is noted that under these conditions:

1. At pH 7.0, a residual of 0.6 ppm. combined available chlorine produces a 100 per cent kill at 22°C., and 1.5 ppm. is required to produce the same result at 4°C.

2. At pH 8.5, residuals of 1.2 and 1.8 ppm. combined available chlorine were required to produce a 100 per cent kill at 22° and 4°C., respectively.

3. Comparisons cannot be made for combined available chlorine residuals at pH ranges above 8.5, as 2.0 ppm., the maximum amount used in these tests, did not produce a 100 per cent kill at 4°C. in 60 minutes. (With 120 minutes of exposure, a residual of 1.8 ppm. of combined available chlorine produced a 100 per cent kill at 4°C.)

4. With free available chlorine, at pH ranges of 7.0 and 8.5, the bactericidal properties are not affected materially by the low temperature, as 100 per cent kills were obtained in 20 minutes with 0.03 to 0.06 ppm. of free chlorine at either 4° or 22°C.

5. With free available chlorine at higher pH ranges—9.8 and, particularly, 10.7—the lower temperature markedly affects the bactericidal efficiency: at pH 9.8, 0.4 ppm. residual was required at 4°C., and only 0.06 ppm. at 22°C.; at pH 10.7, 1.0 ppm. residual was required at 4°C., and only 0.3 ppm. at 22°C.

Effect of Exposure Time

In Fig. 3, the relative efficiency of free and combined available chlorine is contrasted by results obtained at 20° to 25°C., after various periods of exposure. In general, the lines of 100 per cent kill intergrade very nicely for the various time intervals. With both free and combined available chlorine plotted to the same scale, direct comparisons may be made. It is sufficient, perhaps, to note that, under the same conditions of test, the bactericidal efficiency of combined available chlorine residuals with 120 minutes of exposure does not quite equal the efficiency of free available chlorine residuals with one minute of exposure.

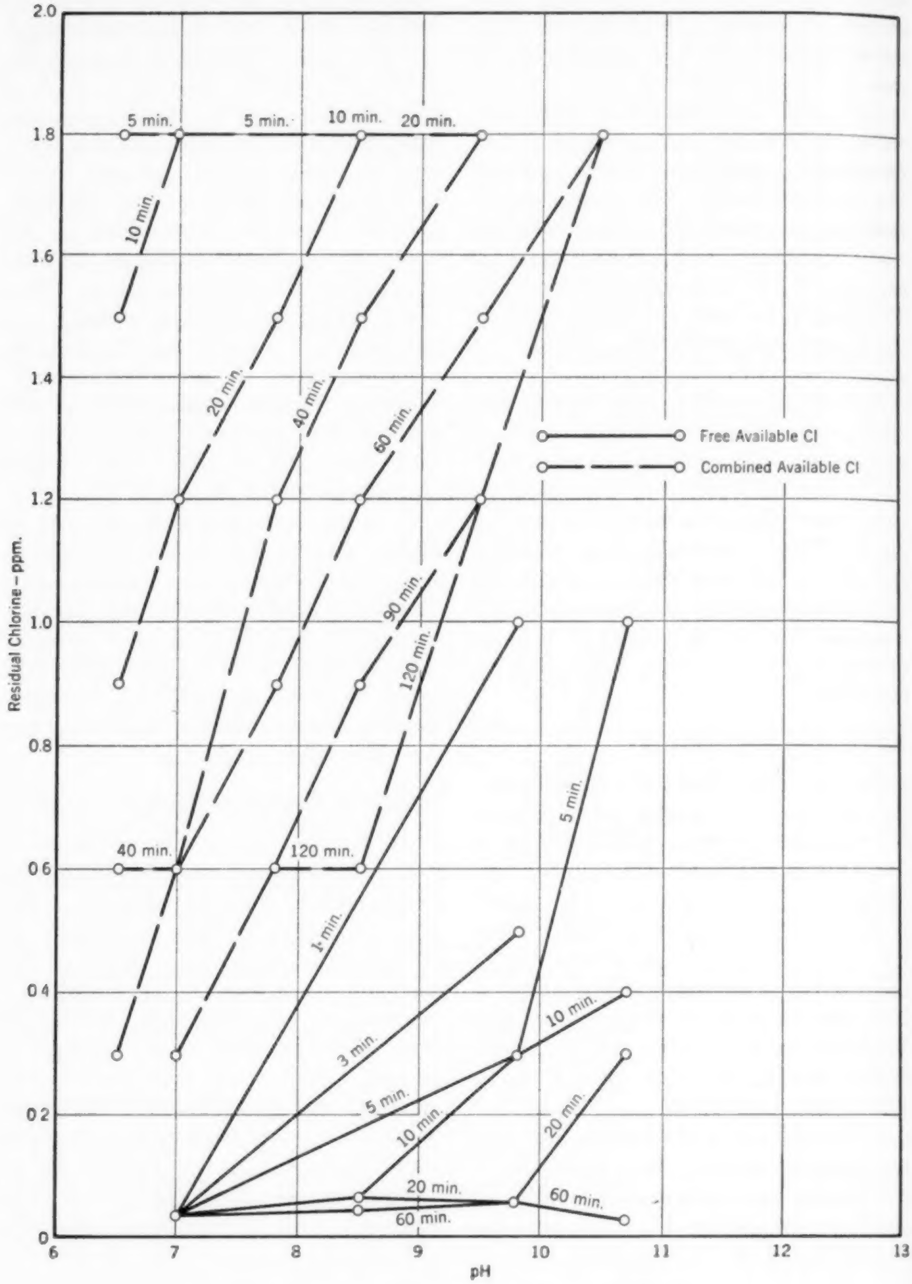


Fig. 3. Time Required for 100 Per Cent Kill

Comparisons of the amounts of free and combined available chlorine residuals required to obtain 100 per cent kills in the same time interval are not possible for periods of less than five minutes, as combined available chlorine, in the concentrations used, did not produce 100 per cent kills in less than five minutes. As a matter of fact, results with chloramine were not consistent for periods of less than about 20 minutes. Table 1 shows the respective amounts of free and combined available chlorine residuals required to produce 100 per cent kills, at various pH values, after 20 and 60 minutes' contact.

These results indicate that, if 100 per cent kills are to be obtained in the same exposure time, 15 to 60 times (average 30) as much combined available chlorine residual must be used, as compared with free available chlorine residuals. Thus, it can be conservatively stated that combined available chlorine is a much less efficient bactericidal agent than free available chlorine. A 100 per cent kill under the same conditions, with the same amounts of free or combined available chlorine residual, will require at least a 100-times longer exposure period for the combined available chlorine. A 100 per cent kill with the same period of exposure will require at least 25 times as much combined as free available chlorine.

Minimum Safe Residuals

It is believed that this evidence of the influence of pH and temperature on the effectiveness of free and combined available chlorine is sufficiently applicable to plant operation with natural waters to justify proposing suggested minimum standards for water chlorination. In formulating such proposals, however, the influence of both pH and temperature must be kept in mind. At high pH ranges—10 to 11—2.0 ppm. of combined available chlorine residual for two hours, or 1.0 ppm. of free available chlorine residual for ten minutes, is not sufficient to produce a 100 per cent kill. With free available chlorine, if the exposure period is increased to 60 minutes, 0.3 ppm. residual is effective at pH 10.7. Similarly, with combined available chlorine, if

TABLE 1

Residuals Required for 100 Per Cent Kills

pH	Required Available Chlorine Residual		
	Free *ppm.*	Combined *ppm.*	Ratio Free: Combined
20-min. Contact			
7.0	0.04	1.2	1:30
8.5	0.07	1.8	1:26
60-min. Contact			
7.0	0.04	0.6	1:15
8.5	0.05	1.2	1:24
9.5	0.06	1.5	1:25
10.7	0.03	1.8	1:60

the time of exposure were increased to four hours, undoubtedly 100 per cent kills would be obtained at this high pH. However, at pH ranges above 9, and particularly above 10, for contact periods of more than one hour, the hydroxyl ions show a marked bactericidal action and the results cannot be ascribed to residual chlorine alone (4).

Figure 4 includes all the data obtained at 20° to 25°C. for 60-minute exposures to combined and 10-minute

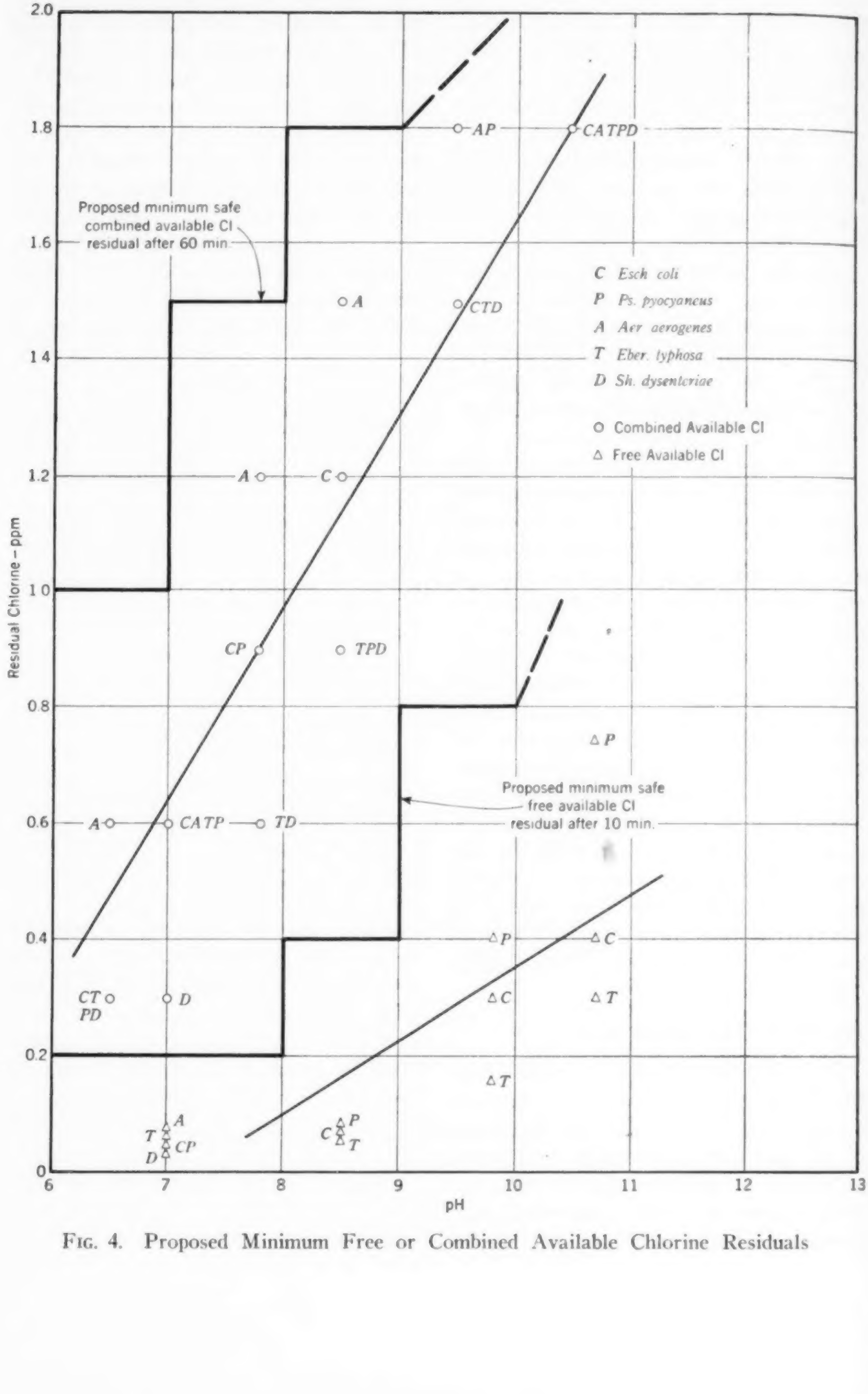


FIG. 4. Proposed Minimum Free or Combined Available Chlorine Residuals

exposures to free available chlorine, with all strains of coli, aerogenes, pyocyaneae, typhosa and dysenteriae tested. Straight lines * have been drawn to indicate the general trend of the 100 per cent kill for all of the strains tested. Indicated, in addition, are the proposed minimum safe residuals for combined available chlorine after 60 minutes of contact between organism and bactericidal agent, and for free available chlorine after 10 minutes of such contact. In setting up these proposed minimum safe residuals it is essential to provide a liberal factor of safety to allow for varying conditions, such as: (1) the frequency with which residual tests are made; (2) the adequacy of operators' training and experience; (3) the reliability of the chlorine feeding method; and (4) variations in flow and in the chlorine demand of the water.

For free available chlorine, with waters of pH 6.0 to 8.0, a safe residual after 10 minutes would be not less than 0.2 ppm.; at pH 8.0 to 9.0, at least 0.4 ppm.; at pH 9.0 to 10.0, at least 0.8 ppm.; and at pH ranges of 10.0 and above, more than 1.0 ppm. or preferably four-hour contact periods. The better solution for the high pH problem, when possible, would be to reduce the pH below 9.0.

For combined available chlorine, with waters of pH 6.0 to 7.0, a safe residual after 60 minutes of contact would be not less than 1.0 ppm.; at pH 7.0 to 8.0, at least 1.5 ppm.; at pH 8.0 to 9.0, not less than 1.8 ppm.; and at pH ranges above 9.0, an undetermined amount. Consequently, for pH ranges of 9.0 and above, it would be better to reduce the pH below 9.0, when possible to do so, or to extend the contact time to four hours. In general, 1.8 ppm. of combined available chlorine residual will produce a 100 per cent kill in two hours of contact at pH 9.5 at either of the temperature ranges investigated.

In the application of these proposed standards, if there is any doubt about the nature of the active bactericidal agent (that is, whether it is free or combined available chlorine) the safe procedure is to assume that all of the residual chlorine present is combined available chlorine and to apply the appropriate standard. Detailed and complete data forming the basis for these proposed standards and observations will be found in the tables of the references cited. The superiority of free available chlorine as a bactericidal agent, when compared with combined available chlorine, is quite evident. In addition, it is believed that the proper use of free available chlorine will eliminate many taste and odor problems.

Conclusions

In general, the primary factors governing the bactericidal efficiency of both free and combined available chlorine are:

1. The time of contact of organism and bactericidal agent—the longer the time, the more effective the disinfection.

2. The temperature of the water in which the contact is made—the lower the temperature, the less effective the disinfection.

* This contrast has also been made using results with combined available chlorine after 120 minutes and with free available chlorine after 20 minutes of exposure without materially altering the trends shown by the lines of 100 per cent kills, particularly if the low-temperature results are included. Consequently, it is believed that the proposed minimums should be the same for these periods.

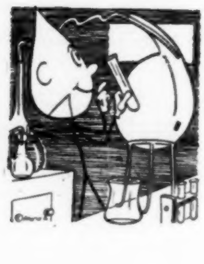
3. The pH of the water in which contact is made—the higher the pH, the less effective the disinfection. Thus, when the combination of high pH and low temperature is encountered, the poorest results are to be anticipated.

Comparing the relative efficiency of free and combined available chlorine, it can be stated that:

1. Under the most favorable conditions—that is, at a pH of 7.0 and a water temperature of 20° to 25°C.—100 per cent kills cannot be obtained with combined available chlorine residuals of about 1.2 ppm. in 10 minutes, but they may be obtained with 20 minutes of contact. Under similar conditions, with free available chlorine, 100 per cent kills are obtained with 0.04-ppm. residuals in one minute of contact.

2. To obtain a 100 per cent kill with the same contact period requires about 25 times as much residual combined as free available chlorine.

3. To obtain a 100 per cent kill using the same amounts of residual combined and free available chlorine, combined available chlorine requires approximately 100 times as long a contact period as free available chlorine.



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Conservation and Regulation in New Jersey

By Roswell M. Roper

A paper presented on May 3, 1948, at the Annual Conference, Atlantic City, N.J., by Roswell M. Roper, Vice-Chairman, Water Policy and Supply Council, and Chairman, Flood Control and Water Supply Committees, New Jersey Dept. of Conservation; and Gen. Mgr., Water Dept., East Orange, N.J.

TO understand the problems of conservation and regulation in New Jersey, a brief description of the physical and industrial conditions of the state may prove helpful. In northern New Jersey, glacial deposits of water-bearing sands and gravels have formed approximately a thousand lakes and ponds. Southern New Jersey also consists principally of water-bearing formations. The western part of the state, being predominantly rural, still enjoys an abundant water supply, both surface and underground. The centers of population and industry lie in the northeastern and central portions of New Jersey and form a belt extending roughly on a line from New York to Philadelphia. This belt, which includes Paterson, Newark, Elizabeth, New Brunswick, Trenton and Camden, constitutes the area of heaviest water consumption in the state.

For almost 300 years after the founding of the first trading station at Bergen, N.J., in 1618, there was no constituted control of the use or diversion of water. This was partly due to the abundant supply and also to the lack of realization by the governing bodies of the state that they could no more divert unlimited quantities of water without harmful results than they could cut down all the trees in the forests without producing quick runoff, erosion and lack of water storage.

About the turn of the century, a Water Policy Commission was formed, and from that time on the various boards succeeding the original commission have endeavored gradually to prevent excessive water waste. The various forms of water commissions, which were shifted by political expediency from one controlling agency to another, gradually acquired regulatory powers over the potable waters of the state. The board members, who served without compensation, did an excellent job in safeguarding the water resources and are to be particularly congratulated on their decision to interconnect all the major supplies during the last war period. This was undoubtedly a factor in maintaining sufficient water for the industries of New Jersey, which ranks eighth in manufacturing in the country and was the nation's wartime arsenal in the East.

In 1945 the Water Policy and Supply Council, under the Dept. of Conservation, took over the powers delegated and assigned to the former commissions. The council was also given the authority to control and develop the Deleware and Raritan Canal.

Rehabilitation work is proceeding with an ultimate goal of developing from 70 to 100 mgd. for industrial use. To put the canal on a businesslike basis, the diversions granted are controlled by meters, and such rates are being

charged as will in the judgment of the council make the canal self-liquidating at the end of a 25-year period.

Although the council controlled all the potable water supplies of the state, including those under municipal and private ownership, it had, at first, no control over the industrial supplies. Thus, the council might grant diversion rights of 2–3 mil.gal. of ground water to one town and 3–4 mil.gal. to an adjacent town or city—where state engineers and the U.S. Geological Survey reported that no interference would occur because of overlapping of cones of depression—only to have an industry buy land between these two towns, drill wells and withdraw millions of gallons of water with no state control. The only recourse of the towns was through the courts.

Realizing the danger of the situation which existed, the council had a bill drawn up and placed before the legislature, covering the control of industrial supplies. As chairman of the New Jersey Section the author presented the matter to the more than 300 members, who promptly passed a resolution approving such legislation. In a short time the bill was enacted by both houses unanimously. This is a good illustration of the cooperation among the various interested organizations.

The council's new responsibility will mean an enlarged engineering and technical staff to correlate and make available a mass of information which has accumulated over the last 300 years.

Another conservation step with which the council is now dealing is flood control, principally in the Passaic Valley area, the section most heavily damaged by floods. In the plans now being prepared in conjunction with the U.S. Army Engineers, part of the flood waters may be retained for water supply, thus providing one more means of conservation.

To be able in the future to cooperate with and give adequate protection to the various areas in the state which are in need of flood control, laws similar to those of New York and Pennsylvania are in the process of preparation and enactment. This in itself is one of the major problems with which the council is presently confronted and will require not only cooperation of the counties and municipalities involved, but also participation by the state.

The ultimate project, on which the council is now working, is to lay out an over-all program for the utilization of the surplus waters of the state in successive steps as increased demands arise in various sections. The basic principles behind this plan have already been approved by Governor Driscoll, as well as by former governors Edge and Larsen, the latter now being Commissioner of Conservation for the State of New Jersey. This program should protect the development of the state water supply for a period of 75 to 100 years.

By formulating this plan and having it as a matter of record, any proposed developments can be studied in relation to the whole picture and supplies can be allocated which will be sufficient for the areas making such requests but will not be detrimental to other areas covered by the master plan.

In this way, it is felt, the citizens and water consumers of New Jersey will be getting a businesslike administration and the best and purest water available. As each major development proceeds, it should be so handled as to give the lowest rates for water consistent with the actual costs of production and the capital and maintenance expenditures necessary to keep the various units of the system operating efficiently.

1948 Conference—Atlantic City

GROWTH was the keynote of the 1948 Conference—growth of the Association in the nine-year war era between visits to Atlantic City. Back in June 1939, when a 3,500-member A.W.W.A. took over the Ambassador and Chelsea Hotels, 1,290 members and guests set a new registration record. And last May it was a 7,000-member A.W.W.A. which took over the same two hotels plus the Ritz-Carlton, and also topped all previous records with a registration of 1,704. But it was less the 100 per cent increase in membership and the 33 per cent increase in attendance than the technical program itself which gave the best evidence of the Association's growth in the interim, for, from May 3 through May 7, 118 scheduled speakers and a host of unscheduled discussers virtually fought their way through an excess of "weather" to talk shop at the eighteen technical sessions held in Atlantic City's Auditorium. What they talked about is listed on pages 1320 to 1322; what they said has been and will continue to be recorded in the text pages of the JOURNAL; and if much of the value of the presentation, the spontaneity of discussion, the real evidences of the Association's vigor cannot be more than hinted at, those who were there for both meetings, at least, can fully appreciate the growth.

As a matter of fact, more than just a biggest-yet, 1948's was a best-yet conference: exhibits, meetings, entertainment were all tops, and were all tops because of the splendid work of the various committees, national and local, which cooperated, coordinated and just plain worked hard to insure the success of the various events.

Heading the list again, was the Convention Management Committee, which functioned smoothly through the combined genius and efforts of:

WILLIAM J. ORCHARD, *Chairman*

Representing A.W.W.A.	*Representing W.& S.W.W.A.*
E. ARTHUR BELL	R. F. HAYES
ROSWELL M. ROPER	E. A. SIGWORTH

Ex Officio

N. T. VEATCH, *President*	DANIEL J. SAUNDERS, *President*
HARRY E. JORDAN, *Secy.*	ARTHUR T. CLARK, *Secy.-Mgr.*
CHARLES H. CAPEN, *Chairman, Publications Com.*	

The technical program, brain-trusted by a committee under the chairmanship of Charles H. Capen, was, as previously indicated, a record-breaker both in quantity and quality. Not only did the majority of the sessions overload the capacities of the meeting rooms, but so many people had so much to say that many of the sessions were forced into overtime. A pronounced success, too, was the move toward increasing the number of panel discussions. And no men-

1948 CONFERENCE STATISTICS

Atlantic City Registration by Days

Day	Men	Ladies	Total
Sunday, May 2	281	91	372
Monday, May 3	659	200	859
Tuesday, May 4	196	49	245
Wednesday, May 5	96	16	112
Thursday, May 6	116	—	116
TOTALS	**1,348**	**356**	**1,704**

Geographical Distribution of Registrants

UNITED STATES

Alabama	19
Arizona	1
Arkansas	1
California	36
Colorado	12
Connecticut	19
Delaware	10
Dist. Columbia	18
Florida	26
Georgia	22
Illinois	111
Indiana	23
Iowa	15
Kansas	11
Kentucky	12
Louisiana	11
Maine	9
Maryland	60
Massachusetts	37
Michigan	38
Minnesota	16
Mississippi	2
Missouri	30
Nebraska	9
New Hampshire	1
New Jersey	250
New York	317
North Carolina	24
North Dakota	3
Ohio	69
Oklahoma	3
Oregon	1
Pennsylvania	279
Rhode Island	21
South Carolina	12
Tennessee	28
Texas	12
Virginia	40
Washington	5
West Virginia	15
Wisconsin	31

OUTSIDE UNITED STATES

Canada	30
Colombia	1
Cuba	4
Hawaii	3
Holland	2
Puerto Rico	2
Mexico	3
TOTAL	**1,704**

Comparative Registration Totals—1939–1948

Year	Place	Men	Ladies	Total
1948	Atlantic City	1,348	356	1,704
1947	San Francisco	1,115	431	1,546
1946	St. Louis	1,303	214	1,517
1944	Milwaukee	1,185	171	1,356
1943	Cleveland	973	158	1,131
1942	Chicago	1,198	240	1,438
1941	Toronto	1,136	309	1,445
1940	Kansas City	1,265	202	1,467
1939	Atlantic City	1,020	270	1,290

Contenders for Section Awards—1948

Henshaw Cup

Ohio	**65.8%**
N. Carolina	63.9%
Arizona	61.8%
Montana	58.7%
W. Virginia	57.0%

Hill Cup

Florida	**24.8 pt.**
Michigan	21.3 pt.
Pac. Northwest	16.9 pt.
Canadian	15.1 pt.
Ohio	12.0 pt.

Old Oaken Bucket

California	**714**
New York	635
Southwest	548
Canadian	455
Illinois	402

tion of the program would be complete without a bow to the local section members who served in the new capacity of Associate Presiding Officers to keep the meetings running smoothly.

With the vast arena of the Atlantic City Auditorium to work in, Arthur T. Clark and his Exhibit Committee spread themselves out over 13,825 sq.ft. of space and put on one of the best and best-organized shows in A.W.W.A. Conference history. Eighty-five exhibitors set up shop in 121 booths and did a land-office business of education and good will.

Joseph M. Wafer's General Entertainment Committee, too, did a bang-up job of planning the play. And with the weather rather rugged and some of Atlantic City's playground features still in hibernation, attendance at the various functions would have pleased a professional promoter. Only events to suffer were the rather muddy golf tournament and the much postponed Ladies' Chair Ride.

Transportation, again the baby of Chairman E. A. Sigworth and his committee, was, as usual, smoothly supervised. Although arrangements were by no means as elaborate this year as last, when the West was to be seen, members still murmured the refrain: "People come and people go, and Sigworth makes it easy!"

And finally, it is to the New Jersey Section that members should bow in giving credit for the efficient operation of the Conference. As always, when every one works, and works together, it is difficult to distribute the orchids equitably, but mention should be made of the work of R. M. Roper, E. D. Sheehan, and C. B. Tygert as chairmen of the host committees, and of Mrs. R. M. Roper's efficient management of ladies' entertainment. To them, and to at least a hundred other local section members and their wives, the success of the Conference was primarily due.

Association Awards

Honorary Membership was conferred upon Charles P. Hoover of Columbus, Ohio, Louis R. Howson of Chicago and Abel Wolman of Baltimore, Md. The citations follow:

Charles P. Hoover, Consulting Engineer and Superintendent of Water Purification, Columbus, Ohio; a member of the Association since 1913; Fuller Award 1943; Past Chairman, Committee on Corrosion Control; *an internationally recognized leader in the development of softening for municipal water supplies.*

Louis R. Howson, Consulting Engineer, Partner, Alvord, Burdick & Howson, Chicago; a member of the Association since 1916; Goodell Prize 1946; Diven Medal 1944; Fuller Award 1943; President 1942; Vice-President 1941; Director 1928–30; Chairman, Committee on Water Works Practice; Chairman, Committee on Steel Standpipes and Elevated Tanks; Chairman, Committee on Survival and Retirement Experience With Water Works Facilities; Chairman, Committee on Valuation and Depreciation; Member, Publication Review Committee, National Water Policy, Federal Activities, Fire Prevention and Protection; *a student of the economics of water supply who shares his knowledge freely with the water works industry.*

Abel Wolman, Consulting Sanitary Engineer; Professor, Sanitary Engineering, Johns Hopkins University, Baltimore, Md.; a member of the Association since 1918; Editor of Journal 1922–37; Diven Medal 1937; President 1943; Vice-President 1942; Director 1939–42; Chairman, Committee on National Water Policy; Chairman, Water and Sewage Works Development Committee; Member, Committees on Water Works Practice, Federal Activities, Valuation and Depreciation; *a leader in the thought and practice of public health engineering.*

The John M. Diven Medal, awarded to the member whose services to the water works field during the past year are deemed most outstanding, was presented to A. Clinton Decker. The citation follows:

A. Clinton Decker, for his highly effective direction of committee activities of the Water Purification Division, which resulted in the completion of the text for the revised edition of the *Manual of Water Quality and Treatment.*

The John M. Goodell Award, granted for the best paper published in the Journal, was presented to Melvin P. Hatcher. The citation follows:

Melvin P. Hatcher, for his paper entitled "Water Works Rules and Regulations," as published in the December 1947 Journal (Vol. 39, page 1165); the paper being timely, constructive and in general informative in the field of water works operation.

The George Warren Fuller Awards were presented to twenty-two men whose Sections had honored them during 1947 and 1948—the period from the 1947 San Francisco Conference up to the beginning of the 1948 Atlantic City Conference—"for their distinguished service in the water supply field and in commemoration of the sound engineering skill . . . the brilliant diplomatic talent . . . and the constructive leadership of men . . . which characterized the life of George Warren Fuller." The list of awardees follows:

Arizona Section—Alden Williams Miller: For his distinguished service and constructive leadership in the Arizona Section of the American Water Works Association.

California Section—Loren Ellsworth Blakeley: For his excellent work and effort in promoting legislation to control ground water pollution.

Canadian Section—Edward Victor Buchanan: For outstanding accomplishments in the administration of water works and public utilities; for leadership in the development of water works practices; and for effective cultivation of desirable public relations.

Cuban Section—Jose Garcia-Montes: In recognition of his leadership in water works engineering in the Republic of Cuba, and for his untiring efforts to help solve the water problems of Havana.

Florida Section—George Ernest Ferguson: For valuable service to the state of Florida in promoting the appraisal of its water resources problems; and for his constructive efforts in promoting the interests of the Section.

Four States Section—Leon Small: For outstanding administrative service and foresighted planning in the development of the present and future water supply for the city of Baltimore. He has enhanced the prestige of that bureau and made it one of the outstanding systems in the country.

Iowa Section—HANS VICTOR PEDERSEN: For his long-term and constructive interest in Association activities; his leadership in the organization of the Iowa Section; as well as his outstanding services to the state while State Sanitary Engineer.

Kansas Section—HARRY WHEELER BADLEY: For individual effort in stimulating interest in building up membership and good will among the water works men of Kansas.

Kentucky-Tennessee Section—ERNEST ELMER JACOBSON: For outstanding service rendered a public water supply organization in the capacity of Manager; for establishing and maintaining excellent public relations; and for his interest, activity and contributions to the water works field.

Michigan Section—JOHN ANTHONY KEILS: His fifty-nine years of active service, and especially the thirty years he has so efficiently managed the Mount Clemens Water Department, is an inspiring example of leadership to the Section and the water works profession.

Missouri Section—THOMAS JULIAN SKINKER: For many years of distinguished service in the water supply field, for the display of sound engineering skill and for his constructive leadership of men.

Montana Section—MALCOLM WADE PLUMMER: For his proven ability with his own employer; his leadership in the water works field as a strong advocate of the training of his technical staff; and for his long and active interest in the Montana Section.

New Jersey Section—HOWARD THOMPSON CRITCHLOW: In recognition of his skillful guidance of water supply agencies in New Jersey to the end that the citizens and industries in the state shall not lack an ample supply of water.

New York Section—JOHN M. DIVEN: For his many years of untiring and ever cheerful service to the Association and Section, conspicuous among which are his very productive membership promotion activities.

North Carolina Section—JOHN RAYMOND PURSER JR.: For his long and outstanding services as instructor in the Water Works Operators' School; and for his cheerful and untiring efforts on behalf of the Section, particularly during the difficult war years.

Ohio Section—PAUL DANA COOK: For his ever present loyalty, wise counsel, energetic guidance and conspicuous, successful leadership to his Section, and for conscientious and effective service to the water supply of his home community.

Rocky Mountain Section—GEORGE JOSEPH TURRE: In recognition of his outstanding contribution to the Water Works School of the Rocky Mountain Section, and for his conscientious and efficient services to the Section.

Southeastern Section—WILLIAM HUGH WEIR: For his valuable services to the Section, particularly his contributions to the growth of the Section during its early years; and for his leadership in the organization of and continuing interest in the Georgia Water Works Short School.

Southwest Section—ALBERT HERMAN ULLRICH: In recognition of his keen interest in Association and Section affairs; and particularly in recognition of his untiring and inspiring efforts on behalf of water works operators.

Virginia Section—CHARLES EDWARD MOORE: In recognition of his many years of efficient and successful management of the water works in the city of Roanoke, and his leadership in the activities of the Virginia Section.

West Virginia Section—ARTHUR ROBERT TODD: In recognition of his long service in the field of water purification, his willingness to aid his fellow workers and his continuing efforts to advance his profession.

Wisconsin Section—JEROME CROSBY ZUFELT: For his outstanding work in developing the proper procedure for fluorination of the water supply at Sheboygan and for his studies of the effect that such procedures have on the general health of the people.

The Nicholas S. Hill Jr. Cup, awarded annually to the Section making the largest weighted gain in membership, was presented to the Florida Section, with a score of 24.8. The runners-up were the Michigan and Pacific Northwest Sections.

The Henshaw Cup, awarded annually to the Section having the greatest percentage of its members present at the Section's annual meeting, was presented to the Ohio Section, which had a score of 65.8 per cent. Following closely, in second and third place, respectively, were North Carolina and Arizona.

The Old Oaken Bucket, as usual, was awarded to the California Section as the largest Section in the A.W.W.A. This marked the ninth consecutive year in which the trophy has been won by the California Section.

Schedule of Conference Papers and Reports

Panel Discussion—10:00 A.M.—May 3, 1948

Rates and Regulations for Water Use by Air-Conditioning Equipment.....Elwood L. Bean, Ted H. Kain, Marsden C. Smith, Frank C. Amsbary and Lynn B. Mighell
Water Conservation and Regulation in New Jersey.....................Roswell M. Roper

Panel Discussion—10:00 A.M.—May 3, 1948

Water Works Conferences and Schools—Their Scope and Value......William T. Ingram, Raymond J. Faust, A. P. Black, H. N. Lendall, Edward R. Stapley and Charles R. Cox

General Session—2:00 P.M.—May 3, 1948

Panel Discussion—The Use of Cone and Butterfly Valves in Distribution Systems......... Laurance E. Goit and Laurie M. Leedom
Operation of Water Works Gate Valves.............................Donald M. Belcher
Practical Aspects of Water Hammer.......................................S. Logan Kerr
Proposed Revision—Specifications for Laying Cast-Iron Pipe..........Joseph P. Schwada

Water Purification Division—2:00 P.M.—May 3, 1948

Short-Period Flocculation and Clarification Basins....R. W. Haywood Jr. and C. F. Wertz
Discussion...H. O. Hartung
Discussion...S. B. Applebaum
The Operation and Control of Small Water Treatment Plants..........Thomas R. Lathrop
Panel Discussion—Water-borne Outbreaks, 1938–45........Rolf Eliassen, Charles R. Cox, I. M. Glace, J. E. Kerslake, A. P. Black, C. K. Calvert and Carl M. Hoskinson

Ground Water Symposium—10:00 A.M.—May 4, 1948

Ground Water Recharge on Long Island........Arthur H. Johnson
Temperature Effects of Recharge Operations........M. L. Brashears
Changing the Course of Ground Water Flow....Loren E. Blakeley and Victor A. Endersby

Water Purification Division—9:30 A.M.—May 4, 1948

The Cultivation and Identification of "Nuisance" Organisms:
Slime-forming Organisms........F. B. Strandskov
Sulfate-reducing Organisms........R. L. Starkey
Iron Bacteria........George D. Norcom
Biological Balance in Impounding Reservoirs........Charles E. Renn

General Session—2:00 P.M.—May 4, 1948

The Development of Ground Water........E. M. Bennison
Policies and Problems in Controlling Ground Water........H. T. Critchlow
Discussion........R. O. Van Meter
Natural Aspects of Artificial Recharge of Ground Water..A. N. Sayre and V. T. Stringfield
A Rational Policy for Control of the Nation's Water Resources........Abel Wolman

Plant Management and Operation Division—2:00 P.M.—May 4, 1948

Symposium—Meeting Major Emergencies in Water Supply........Mark D. Hollis, B. A. Poole, H. H. Gerstein, Arthur Gorman and Ralph E. Noble
New Industrial Fire Hazards........Mathew M. Braidech
A Superintendent's View of Fire Protection Requirements........Samuel F. Newkirk Jr.
Water Requirements for Fire Protection........A. C. Hutson

Water Purification Division—9:30 A.M.—May 5, 1948

Committee reports:
Biological and Chemical Problems of Water Distribution Systems........J. C. Vaughn
Specifications for and Methods of Testing Zeolites........D. E. Davis
Specifications for Filtering Materials........Richard Hazen
Open-Air Reservoirs........Norman J. Howard
Business Session

Water Works Practice Committee—9:30 A.M.—May 5, 1948

Studies of the Properties of Sulfur Jointing Compounds........James W. Estep
Bacterial Oxidation of Sulfur in Pipe Sealing Mixtures........R. L. Starkey
Panel Discussion—Sulfur Jointing Compounds......Wendell R. LaDue, Thomas F. Wolfe, Martin E. Flentje, C. R. Payne, Joseph P. Schwada, Guy C. Northrup, W. V. Weir and George McKay
Experimental Studies of Cathodic Protection for Elevated Storage Tanks....Peter E. Pallo

Finance and Accounting Division—10:00 A.M.—May 5, 1948

Puerto Rico's Water Supply Developments........Sergio Cuevas
Solving Havana's Water Supply Problems......Manuel J. Puente and Jose Garcia-Montes
The Water Works Dollar—Whence Comes It? Where Goes It?........Charles H. Capen
Public Utility Billing and Accounting........A. Knaff

General Session—2:00 P.M.—May 5, 1948

Dealing With the Public in Obtaining Rate Increases.............Leonard N. Thompson, Rennie I. Dodd, Percy A. Shaw, W. R. Wise and R. G. Yaxley
The Outlook for Municipal Bonds.................................Frederick L. Bird
Service Extensions to Suburban Areas. Rates for Suburban Water Users.............. S. T. Anderson, G. E. Arnold, M. B. Cunningham, C. M. McCord, H. B. Miles, W. C. Morse, Paul Weir and W. Compton Wills

Forty Years of Chlorination—2:00 P.M.—May 5, 1948

The First Step—Chicago 1908.......................................C. A. Jennings
Controlling the Green Goddess.......................................M. F. Tiernan
Pioneers in the Development of Chlorination..........................Harry A. Faber
Chlorine as a Water Treatment Material...............................Gordon M. Fair

Symposium—10:00 A.M.—May 6, 1948

The Public Relations Program—An Appraisal:
The Objectives...R. B. Cooney
Dealing With Public Officials.....................................M. B. Cunningham
Selling the People a Project......................................Kenneth V. Hill
Paid Advertising a Useful Tool...................................Walter S. Byrne
Promoting Good Publicity...Don O'Reilly
Making Friends of Customers...E. L. Filby
Halifax Consistent Program...Norma Nelson
Objectives Reached?...Harry E. Jordan

Boiler Feedwater Research Committee—9:30 A.M.—May 6, 1948

Treatment of Municipal Water Supplies for Industrial Purposes..............R. B. Martin
Removal of Hydrogen Sulfide From Water.........................Sheppard T. Powell
Foaming and Carry-over in Boiler Operation.............................R. W. Seniff
Silica Removal With Iron Shavings....................................Walter B. Leaf
Water Problems in Diesel Locomotive Operation..........................M. A. Hanson

Plant Management and Operation Division—2:00 P.M.—May 6, 1948

A New Automatic Pumping Pressure-Flow Control System.............Marsden C. Smith
Designing Pumping Stations for the Medium-Sized City..................Francis S. Friel
Steel Water Pipeline Appurtenances...............................Laurance E. Goit
Steel Pipe Ring Girder Construction.....................................G. H. Garrett

Watershed and Reservoir Problems—2:00 P.M.—May 6, 1948

Panel Discussion—Public Use of Reservoir Lands and Waters—Public Relations Aspects.... *Led by* L. S. Finch
Gerald E. Arnold, S. T. Anderson, R. E. Bonyun, Eugene F. Dugger, Charles E. Moore, Edward S. Hopkins and Harry B. Shaw
Panel Discussion—Reservoir Lands Pay Their Way...............*Led by* Earnest Boyce
Wendell R. LaDue, George F. Hughes, Percy A. Shaw and John M. Heilman

Water Works Practice Committee—9:30 A.M.—May 7, 1948

Open Session—Recommended Practice for Painting Elevated Tanks

Papers Scheduled at 1948 Section Meetings

THERE follows a chronological listing of papers scheduled for presentation at 1948 Section Meetings. The dates of the Section Meetings from 1944 to 1948 and locations for 1948 are given on page 1336. Section officers who were elected at meetings held during 1948 are listed on page viii of this issue.

Kansas Section—March 11–12, 1948

Panel Discussion:
- Increased Cost of Operations and Its Effect on Rates ... Robert S. Millar
- Cost Trends in Water Production ... Robert H. Hess
- Cost Trends in Water Distribution ... L. L. Weatherford
- Effects of Present Costs on Rates ... Walter F. Johnson
- Future Trend of Rates ... A. P. Learned

Cross-Connections ... W. Scott Johnson

The Historical Development of Sewage Treatment ... George S. Russell

Panel Discussion:
- Sewer Maintenance ... George J. Fisher
- Problems of Financing Sewage Treatment ... C. Madison Williams
- Operation Problems ... Lester T. Hagadorn

Panel Discussion:
- Maintenance Practices ... Alar Mawdsley
- Maintenance in the Pumping and Filtration Plant ... A. W. Rumsey
- Maintenance of Distribution System ... Dorr Pelton
- Maintenance in the Small Department ... George W. Pate Sr.
- Maintenance of Fire Hydrants ... B. H. Van Blarcum

Present-Day Methods of Water Main Cleaning ... J. A. Frank

Panel Discussion:
- Operating Problems and Their Effect on Public Relations ... Frank E. Willey
- Treatment Problems and Public Relations ... V. E. Houghland
- Service Problems and Public Relations ... H. H. Kansteiner
- Collection and Record-Keeping Problems and Public Relations ... F. D. Diehl

Can You Read a Meter? ... Harry A. Badley

The Question Box ... E. J. Allison

New York Section—April 1–2, 1948

Address of Welcome ... *Mayor* Frank J. Costello

Syracuse Extends Its Third Conduit ... Elon P. Stewart

Modern Electrification of Water Works ... H. V. Crawford

Kodak Park Lake Pumping Station ... Allen C. Bailey

Manufacture of Prestressed Concrete Cylinder Pipe ... Philip Hirsch

Discussion Program ... *Led by* Simon P. Carman

Arizona Section—April 2–4, 1948

Address of Welcome ... *Mayor* Guy V. McGowan

History and Development of the Globe Water Supply ... Guy V. McGowan

Cathodic Protection ... Frank P. Macdonald

History, Development and Manufacture of Welded Steel Pipe ... Vic H. Householder

Small Activated Sewage Treatment Plants ... Miles A. Lamb

An Assumption Times an Assumption Divided by an Assumption Equals a Positive Fact..... John Girand
Operators' Roundup.......................................*Led by* Reamy C. Fitch
Round Table Discussion of Papers.......................*Led by* John A. Carollo
Buckeye Sewerage System.......................................R. M. Cushing
Mesa Water System..John Hoover
Arizona Ground Water Resources...................................S. F. Turner
Muddy Water and How It Got That Way......................Milton G. Sanders
Double Mains...Clark Webb
Harnessing Liquids...*A Motion Picture*
Round Table Discussion of Papers.......................*Led by* John A. Carollo
Operators' Roundup.......................................*Led by* Reamy C. Fitch

Montana Section—April 9–10, 1948

Address of Welcome....................................*Mayor* Homer Terwilliger
Response..Joseph M. Schmidt
Round Table Discussion....................................*Led by* John Hazen
Lifeblood of the Land...*A Motion Picture*
More Adequate Health Protection for the People of Montana..............B. K. Kilbourne
Municipal Water Considerations in the Over-All Resource Development Program in the Missouri Basin..S. J. Ware
Discussion—Water Handling Between the Tap and the Consumer.........L. O. Williams
Availability of Material and Construction Costs..........................John Morrison
Silt Control...L. Filaseta
River Basin Developments in Montana......................................Fred Buck

Canadian Section—April 12–14, 1948

Guided Discussion—Water Main Crossings at Railways, Bridges, Rivers and Roads......... *Led by* R. H. Martindale
Taste and Odor Control in Water...C. R. Cox
Symposium—Accounting: A Necessary Evil.....................*Led by* R. L. Dobbin, M. W. Rogers, G. F. Shreve, S. H. Gillet and E. L. Gothard
Guided Discussion—The Use of Tapping Sleeves and Valves Under Pressure, and the Insertion of Line Valves in Mains Under Pressure..............*Led by* C. J. Des Baillets
Conservation and Water Supply..A. H. Barnes
Guided Discussion—Water Waste Surveys........................*Led by* H. R. Hooper
Canadian Water Supplies for Industrial Uses............................J. F. J. Thomas
Water Supply to Rural Vancouver..W. H. Powell
Guided Discussion—Miscellaneous Water Works Problems...........*Led by* N. MacNicol

Illinois Section—April 15–16, 1948

Planning for Chicago's Future Water Needs...........................W. W. DeBerard
Is Induced Precipitation Practical?......................Glen E. Stout and W. J. Roberts
Training Water Works Personnel..S. C. Casteel
Discussion...Clifford Fore
How to Determine the Correct Meter Size and Service Size for a New Water Consumer..... A. P. Kuranz
Discussion...
The Importance of Development Work in Water Well Construction.........E. W. Bennison
Discussion...C. L. Waterbury
Guided Discussion—Pumping, Distribution and Tanks................*Led by* Edward E. Alt
What We Hope to Accomplish With the Electron Microscope...............John R. Baylis
Some Practical Aspects of Synthetic Detergents.............................R. E. Hauber
Discussion...James Vaughn
Guided Discussion—Problems in Water Purification..............*Led by* H. E. Hudson Jr.

Indiana Section—April 21–23, 1948

Financing Water Works Improvements....................................David N. Brewer
Discussion...O. J. Stewart, M. Warner, Jr.,
Charles E. Scholl, Ralph E. Roop, M. H. Schwartz and William F. Lebo
Corrosion and Incrustation of Well Screens..................................G. F. Briggs
Discussion...N. E. Gunderson, A. R. Klein,
O. M. Leonard, W. E. Howland, James West and Lewis S. Finch
A Procedure for Disinfecting Water Mains..................................C. K. Calvert
Discussion.........William C. Shoemaker, Leo Besozzi, B. A. Poole and Linn H. Enslow
Lining Small Water Mains in Place.......................................Alfred B. Anderson
Discussion...............T. Edwin Milligan, Nelson Stone, Max Stearns and J. A. Frank
Paints and Protective Coating...W. T. McClenahan
Discussion...................................Frank P. Macdonald, Frederick V. Kroeber,
H. J. Draves, O. A. Newquist, Jack Gordon and W. E. Howland
Some Studies on Break-Point Chlorination..................................Richard Coote
Discussion..Paul Laux,
Marshall P. Crabill, D. A. Gunder, Albert G. Vinick and George G. Fassnacht
Leak Survey...Luther Younce
Discussion...Cyrus R. Bird, Robert E. Price,
J. B. Wilson, Warren Swartz, A. B. Daugherty and Othmar W. Pies
The Selection and Care of Water Meters..................................Charles Bachman
Discussion..........................M. H. Foley, Clyde Hum, Andrew K. Richardson,
A. C. Gutsch, H. W. Niemeyer and Don E. Bloodgood

Nebraska Section—April 22–23, 1948

Address of Welcome..*Mayor* Clarence G. Miles
Greetings From National Headquarters ....N. T. Veatch Jr.
Comments on Recent Water Works Conference at University of Nebraska..Niles H. Barnard
Corrosion of Metals in the Water Works Industry........................John C. Detweiler
Life Stream...*A Motion Picture*
Postwar Progress in Water Works Operations.............................Melvin P. Hatcher
Panel Discussion:
1. Employees' Benefits..
2. Distribution System Operations..
3. Meter Reading and Testing Practices...
4. What Do You Expect From Nebraska Section, A.W.W.A.?.................................
Ralph H. Lancaster, George C. Pardee,
Clarence W. Burdick, Guy E. Bell, F. A. Raasch and Vern Livingston
Fuel Oil Costs and Deliveries...J. A. Nelson
Natural Gas as a Source of Prime Mover Power......................................J. H. Innis
Diesel Reconversion to Natural Gas...George Wort
Electric Meter Installations and Practices.......................................R. Rieber
Panel Discussion—Extension of Utility Services in Respect to the Growth of the Community
Led by Harold Hoskins

Pacific Northwest Section—May 13–15, 1948

Address of Welcome..*Mayor* Potter P. Howard
Response..S. J. Benedict
The Boise Water Supply—Hot and Cold...H. R. Vinson
Discussion...
Legal Aspects of Water Rights for Domestic Supply.................................Mark Kulp,
Rodney Ryker and Charles E. Stricklin
Radio Communications in Water Works Operation...............................J. Guy Eernisse
A G.I. View of European Water Supply...John Geren

Questions and Discussion
The Use and Development of the Cedar River Watershed.......Allen E. Thompson
Questions and Discussion
Report of Licensing and Short Course Committee.......Curtiss M. Everts
Report of Cross-Connections Committee.......Jerry Allen
Public Relations Forum.......*Led by* Thomas H. Judd
Human Relations Are So Human.......Adam S. Bennion
Questions
Guided Discussion—Public Relations Committee
Panel Discussion—Retirement.......William J. Speir, Donald C. Sampson and Jerry Sayler
Discussion
General Restriction on Domestic Irrigation.......V. L. Goodnight, Samuel Cromwell, E. A. Knittel and W. W. Tinniswood
Discussion
City Planning and a Solid City Structure.......J. Haslett Bell
Guided Discussion...George R. Phillips, Oren L. King, William P. Hughes and W. C. Morse
Discussion
Forum—Water Treatment.......Winston H. Berkeley, C. R. Harlock, John B. Gearhart and Marion Sterling
Discussion
Panel Discussion—Housekeeping.......Mart Early, C. J. Phillips, Gordon Warner and W. C. McElmon
Discussion
Maintenance of Service Reservoirs.......A. H. Labsap, A. G. Volpp, Fred D. Jones and O. E. Hill
Discussion
Strengthening an Existing Distribution System.......Fred C. Stewart
Discussion
Present Status of Fluorides in Public Water Supplies.......Walter Pelton
Discussion
The Need for Increased Water Rates.......Louis R. Howson
Discussion

Kentucky-Tennessee Section—August 23–25, 1948

Address of Welcome.......*Mayor* Hugh P. Wasson
Response.......F. C. Dugan
Recent Advancement in Water Treatment.......A. P. Black
Federation of Sewage Works Association Activities.......V. M. Ehlers
Clean Waters.......*A Motion Picture*
Some Aspects of Waste Disposal at Atomic Energy Plants.......Arthur E. Gorman
Panel Discussion—Distribution Problems and Maintenance Kinks.......*Led by* R. F. Taylor and Lois Sutherland
Panel Discussion—Why Bother With Meter Maintenance?.......*Led by* C. H. Bagwell and B. E. Payne
Panel Discussion—Short Cuts and Labor-Saving Kinks.......*Led by* B. M. Downs and Grant S. Bell
Panel Discussion—Safety in Water Works—Accidents, Their Cause and Prevention.......*Led by* M. B. Whitaker
In-Plant Training.......W. A. Hardenbergh
Radiation Sanitation.......Abel Wolman
Panel Discussion—How Can We Improve Our Annual Meeting?
Panel Discussion—Public Relations.......*Led by* C. M. McCord and H. M. Gerber
Panel Discussion—What Constitutes Good Records?.......*Led by* J. Wiley Finney and George D. Reed
Panel Discussion—Maintenance of Equipment....*Led by* G. R. Kavanagh and Steve Watkins

Panel Discussion—Water Purification.......................... *Led by* W. H. Lovejoy
Coagulation...C. V. Swearingen
Filtration...John J. Quinn
Chlorination, Taste and Odor Control.....................................M. L. West
Panel Discussion—Well Water Supply Problems—Do You Have Any?................
Led by R. T. Hosman
Panel Discussion—Collection Practices........................ *Led by* E. E. Jacobson
Discounts and Penalties...M. L. Brickey
Adjusting Abnormal Bills..H. L. Reeves
Nuisance Complaints...

Minnesota Section—September 1–2, 1948

Address of Welcome.. *Mayor* Garnet Coulter
Response...W. D. Hurst
Maintenance and Operational Problems of the City of Winnipeg Water Works System......
N. S. Bubbis
Analysis of Water Works Operating Data..
George J. Schroepfer, A. S. Johnson, Harris F. Seidel and M. B. Al-Hakim
The Necessity for and Methods of Adjusting Rate Structures to Meet Rising Costs of Labor and Materials..Louis R. Howson
The Development of Ground Water Supplies..............................E. W. Bennison
The Proper Design of Elevated Storage in Semi-arid Areas...............John M. Glasgow
Life Stream...*A Motion Picture*
Modern Developments in the Design and Construction of Water Treatment Plants........
E. L. Lium
Discussion.. *Led by* O. E. Brownell
Planned Maintenance of Water Works.......................................Alfred Schroeder,
Edgar W. Johnson and R. M. Jenson
The Use of Chlorine Dioxide in Water Treatment.........L. H. Coult and Wallace Johnson
Symposium on Public and Employee Relations...............................A. J. Taunton
Discussion.. *Led by* Leonard N. Thompson
Disinfecting Water Mains and Reservoirs.................................Arthur F. Mellen
Discussion...............................W. W. Towne and Jerome H. Svore
The Design and Installation of Larger Meters...........................E. W. R. Butler

Rocky Mountain Section—September 16–17, 1948

Address of Welcome..*Mayor* Ben Nelson
Current Problems of the Water Works Industry.........................Harry E. Jordan
Chlorination...Harry A. Faber
Discussion..O. J. Ripple
Water Service Interruptions..Harvey Munn
Water Water Everywhere...*A Motion Picture*
Construction Costs...Robert L. Streeter
Discussion..H. G. Watson
The Cheyenne Municipal Water Supply.......................................F. M. Veatch
Discussion..Ray L. Sherard
Public Relations..Lewis Dodson
Discussion..K. E. Darling
Round Table Discussions:
Need for Rate Revisions...*Led by* Harry E. Jordan
Unaccounted-for Water...*Led by* Dan Homan
Ground Water...*Led by* Don Warner
Round Table Discussion—Water Main Disinfection.....................*Led by* C. T. Wright
Round Table Discussion—Public Use of Reservoir Lands and Water....*Led by* Ray Sherard
General Round Table Discussion...................................*Led by* H. G. Watson
Current Practice in Water Main Extensions..................................Dan Homan

Michigan Section—September 22–24, 1948

Address of Welcome....................*Mayor* Edward J. Viall
News of the Field....................John E. Vogt
Advantages and Disadvantages of "Upflow" Water Softening Equipment....................
Warren A. Kramer
A Bacteriological Survey of Home Zeolite Softening Units....................W. L. Mallmann
The Flint Water Supply....................Claude Burdick
Cadillac Now Operates Its Own Department....................Everett G. Reiser
Symposium on the Problems of the Smaller Water Works Systems:
Wells—Selection of Site, Minimum Design Details, Development, Selection of Type, etc....
Led by T. L. Vander Velde
Pumping Equipment—Selection, Operation and Maintenance..*Led by* Harrison H. Caswell
Water Conditioning—Iron Removal, Filtration, Softening, Taste and Odor Control, etc.....
Led by Carl E. Dennis
Distribution—Breaks, Freeze-ups, Leaks, Corrosion, Jointing Materials, Disinfection of Pipe, Types of Pipe, Extensions, etc....................*Led by* Anthony Eiker
General Discussion—Meters, Meter Reading, Billing, Collecting, Consumer Complaints, Public Relations, etc....................*Led by* Philip H. Beauvais

West Virginia Section—September 29–30, 1948

Address of Welcome....................Roy F. Ash
Operation of New Softening Plant at Princeton....................Nick Leshkow
Water Water Everywhere....................*A Motion Picture*
Planning Your Maintenance Program....................Harry E. Jordan
Guided Discussion....................*Led by* D. H. Clark
Intake Troubles....................W. D. Kelley
Chemical Feeding....................H. K. Gidley
Coagulation and Sedimentation....................William Kirchman
Filter Problems....................P. W. Tingley
Chlorination....................Archie Adams
Meter Maintenance and Repairs....................G. S. Bradley
Construction of Prestressed Concrete Tanks....................*A Motion Picture*
Water Supply Improvements at Martinsburg, W.Va......M. M. Reynolds and Roy H. Ritter
Effect of Time and Temperature on Water Samples Prior to Bacteriological Examination....
K. E. Cox
Round Table Discussion—Operating Costs and Water Rates....................Cecil C. Coffield,
Max K. Jones and F. M. Offutt
Rules and Regulations Governing Water Utilities....................E. H. Morris
The State Health Department....................N. H. Dyer
The Ohio River Compact and Others Operating in the United States....................K. S. Watson
Fluorine and Tooth Decay....................O. C. Hopkins and George A. Nevitt
Sewer Financing....................Roy H. Ritter

Iowa Section—October 5–6, 1948

Address of Welcome....................*Mayor* J. M. Poole
Response....................Joe J. Hail
Panel Discussion—Water Rates....................*Led by* M. K. Tenny
Rate Adjustment to Meet Increased Costs....................Vernon Kneer
Rates Charged Outside City....................Roy O. Ellis
Reaction of Consumers to Increased Water Rates....................C. W. Hamlin
Panel Discussion—Industrial Consumption....................*Led by* John W. Pray,
Russell Peterson and Frank Meier
Panel Discussion—Iowa Water Resources....................*Led by* H. V. Pedersen
Rainfall and Its Effects Upon Water Supply....................Lawrence C. Crawford
Underground Sources....................R. W. Brooks
Surface Supplies....................Mark E. Driftmeier

Training Water Works Personnel....................Earle L. Waterman
Planned Retirement for Water Works Employees....................Dale L. Maffitt
Cathodic Protection for Elevated Tanks....................Joe J. Hail

Ohio Section—October 7-8, 1948

Address of Welcome....................*Mayor* Roy W. Vaughn
Report on Water Works Short School....................G. A. Hall
Mansfield Water Supply Program and Progress Report....................B. V. BeVier
Stretching Income to Survive Inflation, Including Water Main Extension Policies........ Ray Fuller
Discussion....................Willard Smith
Discussion....................A. H. Klein
Results of Quality of Water Survey in Ohio....................C. V. Youngquist
The Marietta Water Supply Problem....................E. S. Merriam
Discussion....................H. A. Spindler
General Discussions:
Conservation and Rationing of Water....................*Led by* B. V. BeVier
Size and Spacing of Fire Hydrants....................*Led by* Harry L. Krieger
Prevention of Fire Hydrants From Freezing....................*Led by* Harry L. Krieger
Lime Sludge—Use and Disposal....................*Led by* C. C. Whysall
The Country Doctor Prescribes for Ills of a Water Works System....................R. D. McGill
Discussion....................Donald D. Heffelfinger
Discussion....................Joseph C. Hapgood
Discussion....................J. P. Reinheimer
Swimming Pool Operation....................F. J. McIntyre
Dry Ice for Recarbonation....................F. G. Gedge
Rules and Regulations Governing Cross-Connections....................L. E. Wickersham
Significance of Nitrates in Water Supplies....................F. H. Waring
Residual Chlorine Recording Apparatus....................L. A. Marshall
General Discussion:
Type and Sizing of Meters
Benefits Derived From A.W.W.A. Public Relations Program
What Has Been Accomplished in the District Meetings
Packing to Be Used in Laying Cast-Iron Pipe
Meter Reading and Testing Practices
Labor Relations and Wage Problems
What Has Been Learned From Bacteriological Tests of Distribution Systems
Wells and Pumps

Southwest Section—October 11-13, 1948

Address of Welcome....................*Mayor* H. Y. Cartwright Jr.
Response....................M. B. Cunningham
Ground Water—Our Most Abused Natural Resource....................Nicholas A. Rose
Panel Discussion—Building Costs and Bonding Limitations....................N. P. Turner, C. C. Crutchfield and R. M. Dixon
Control Equipment for the Water Works Plant....................L. R. Bagwell
Chlorine Dioxide in Taste and Odor Control....................R. N. Aston
Panel Discussion—Cross-Connections...F. W. McDonald, Clyde R. Harvill and Carl A. Nau
Algae in Fresh Water....................J. K. G. Silvey
Municipal Purchases of Water Works Material....................Homer A. Hunter
Panel Discussion—Water Main Extension Policies....................J. C. Goble, W. F. Ayres and W. F. McMurry

Alabama-Mississippi Section—October 13–15, 1948

Address of Welcome .... *Mayor* John L. Goodwin
Recent Advances in Water Treatment .... A. P. Black
  Discussion .... William E. Johnson
  Discussion .... Paul Krebs
Consumption, Conservation, Waste and Leaks .... H. E. Beckwith
  Discussion .... T. M. Lowe
  Discussion .... Frank Crowe
Distribution System Disinfection .... M. E. Henley
  Discussion .... Glen W. Cowham
  Discussion .... R. M. Striger
Municipal Well Water Supplies .... Frank Hall
  Discussion .... T. H. Collins
  Discussion .... Tip H. Allen
Internal Corrosion and Its Prevention .... Sherman Russell
  Discussion .... John E. Gran
  Discussion .... E. M. Stickney
Alabama's Stream Sanitation Program .... J. C. Clarke
  Discussion .... Gilbert H. Dunstan
Financing Distribution System Extensions .... A. O. Norris
  Discussion .... E. L. Myers
  Discussion .... George Godwin

Arizona Section—October 15–17, 1948

Address of Welcome .... J. P. Ward
Water and Sewage Laboratory Procedures .... H. Gilbert Crecelius
Water Pollution Control Act .... Wright L. Felt
New Collection and Disposal System in East Kingman .... E. Ross Householder
Operators' Roundup .... Guy A. Rhoads
Open Discussion—Who Pays for Main Extensions? ....
Sewer Pipe Jointing—Progress Report .... Harvey W. House
Pipe Locators and Leak Detectors .... Curt R. Fisher
Cross-Connections and Public Health .... W. Readey
Fire Hydrant Standards .... Walter R. Staby
Fire Protection .... John H. Culton
Elevated Tank Maintenance .... J. D. Baughman
Operators' Roundup .... Guy A. Rhoads
Recent Advances in Water Treatment .... A. P. Black
Pumps .... A. B. Barrow
Engine-Driven Water Works Equipment .... Sam S. Headman
Inserting Gate Valve and Valved Branch in Line Under Pressure .... A. J. Manahan

Four States and Western Pennsylvania Sections—October 20–22, 1948

Greetings .... Elbert J. Taylor
Does the Future Call for a Tri-State Water Supply Project on the Delaware River? .... James H. Allen
Chlorine Dioxide Treatment of the Ohio River .... Arthur H. Todd
Pennsylvania Law and Public Water Supply Pollution .... Francis J. Gafford
Flocculation and Sedimentation:
  Flocculators .... W. A. Darby
  Accelators .... A. A. Kalinske
  Precipitators .... Durando Miller
  Double-Deck Basins .... O. D. Voigt
Water Supply and Fire Prevention .... Samuel F. Newkirk Jr.
Ozonation at Philadelphia .... Elbert J. Taylor
Micro-Flora in Water Supplies .... *A Motion Picture*

Departmental Operations:
Legal........John H. Murdoch Jr.
Rate Regulation........Paul L. Holland
Design........D. E. Davis
Watershed Sanitation........Carl Hechmer
Multiple Telemetering Over a Single Telephone Circuit..John H. Henderson and J. M. Jester
Municipally Owned Water Works in Pennsylvania........J. H. Ferguson
Effect of Use of Water Works Income for General Municipal Purposes........R. C. Beckett, J. R. Hoffert and J. R. McComas
Supplementary Method for Bacteriological Examination of Water........L. Gonshery and Norman C. Lasser

Missouri Section—October 24–26, 1948

Address of Welcome........Garvin Dyer
Response........Samuel Marsh
Response........Roger Higgins
Minimum Wages, Salaries and Fees........J. G. Rousch
Cathodic Protection:
Equipment, Capacities and Costs........R. H. McLeod
Actual Installations, Costs of Operation and Results........F. E. Dolson
Economical Pipe Sizes........Vance C. Lischer
Methods of Joining Pipes and Emergency Connections........Meyer Serkes
More Income to Meet Rising Costs:
Why More Revenue Is Needed........W. S. Baum
Rates for Water Service........Melvin P. Hatcher
Discussion........
The Organization and Financing of Extensions to Existing Systems........Burton Oliver
Rules and Regulations Covering Water Extension........W. Victor Weir
Break-Point Chlorination—Pro and Con:
Pro........Herbert O. Hartung
Con........W. Poston
Pro........Raymond F. Bishop
Con........Raymond Piner
Public Relations—National and State........E. L. Filby and C. E. Schanze

Virginia Section—October 25–26, 1948

Water Supply Conservation........Donald S. Wallace
Discussion........*Led by* O. C. Hopkins
Recent Advances in Water Treatment........A. P. Black
Cleaning Pipelines........W. A. Grant
Discussion........*Led by* X. D. Murden
Design and Construction of a Water Collection and Transmission System...*A Motion Picture*
Installation of a 36-in. Valve Inserted Under Pressure in a 36-in. Cast-Iron Pipe Main........*A Motion Picture*
Rules and Regulations Covering City Water Connections, Policy, Location and Increases in Per Capita Usage for Future Planning........Charles E. Moore
Discussion........*Led by* M. C. Smith
Experiences in City Water Service........Whitworth Cotten
Discussion........*Led by* L. R. McClung
Painting of Concrete Structures, Pipelines, and Water Equipment........C. L. Crockett
Discussion........*Led by* B. L. Strother
Question Box........H. E. Silcox

Wisconsin Section—October 28–29, 1948

Atomic Power........*A Motion Picture*
Address of Welcome........*Mayor* Charles A. Beranek
Depreciation of Utility Property........Asel Colbert

Panel Discussion—Depreciation..*Led by* J. Zufelt, W. Peirce, A. P. Kuranz and H. T. Rudgal
Water Hammer Due to Valve Closures..................................Philip S. Davy
Valves in the Water Distribution System...............................Frank J. Egan
Panel Discussion..*Led by* Harold L. Londo
The Test of Time..*A Motion Picture*
Quantitative Determination of Ground Water in Wisconsin..................W. J. Drescher
Getting Water From the Ground..J. W. Gibb
Panel Discussion—Ground Water..E. F. Bean, Harvey E. Wirth, Joe Egerer and Morris O. Nelson
Lake Intakes...Thomas M. Niles
Significance of Present-Day Chlorination Practices.......................N. S. Chamberlin
Panel Discussion—Information Please..................................John R. Baylis, James F. Kerslake, William U. Gallaher, M. J. Shoemaker and Thomas M. Niles

California Section—October 26–29, 1948

Address of Welcome...*Mayor* Walter C. Davison
Response...H. Arthur Price
The Relationship of the Water Utility to the City and City Departments.................. G. E. Arnold and C. P. Harnish
Review and Discussion of California Section A.W.W.A. Standards of Recommended Minimum Requirements for Safe Practice in the Production and Delivery of Water for Domestic Use...L. J. Alexander
Destruction and Preservation of Records...............................Everett L. Clark
Safety Training Program..George Fish
Purchasing...W. R. Foster
Why So Much Paper Work?..Frank Twohy
Panel Discussion—Water Main Extension Policy...................Charles B. Parbury, S. Kelso Velliquette and Philip F. Walsh
Maintenance of Electric Motors.......................................F. W. Pollard
Gate Valves: Uses and Limitations....................................M. K. Socha
Consumer Complaints and Their Relation to Management and Operations..Lawrence L. Camy
Centrifugal Pumps: Applications and New Developments..................H. A. Mylander
Round Table Discussion—Water Works Problems.........................George Yackey
Water Quality Control in California...............Frank M. Stead and Edward A. Reinke
Some Factors in the Biology of Sweetwater Lake.....................Martin W. Johnson
Effect of Water Quality on Ornamental Plants.........................Harold E. Pearson
Use of Quaternary Compounds as Algacides and Bactericides.......................... Charles L. Senn and Henry F. Eich
Discussion...Henry G. Neumann
The Mechanism of Flocculation as Applied to the Clarification of Turbid Waters........... W. F. Langelier and Harvey F. Ludwig
Round Table Discussion of Modern Clarification Practices. Clarification With Activated Silica, Recent Developments and Operation Experiences.............Roy E. Wright
Discussion.......................................*Led by* William W. Aultman
California and the Colorado River..................Milton J. Dowd and Franklin Thomas
Labor Management Relations..Thomas F. Neblett
Discussion...Duncan A. Blackburn
Advantage of Water Utility Construction Work by Force Account............S. B. Nelson
Water—A Raw Material for Industry..................................W. J. O'Connell
Achievements and Opportunities of the A.W.W.A.......Harry E. Jordan and Ray L. Derby

New Jersey Section—November 4–6, 1948

Symposium on Underground Water................................*Led by* Virgil F. Every
Well Construction..*A Motion Picture*
New Jersey Underground Supplies.....................................Thurlow C. Nelson
Depletion of Underground Water Resources in New Jersey............Henry C. Barksdale

Recharge Methods for Restoring Depleted Underground Supplies in Newark Industrial Area .... Edwin T. Erickson
Summary .... R. M. Leggette
Report of Section's Water Supply Committee .... Howard T. Critchlow
Record-Keeping for Water Utilities .... Albert C. Brason
Question Box .... *Led by* Martin E. Flentje
Public Relations Aspect of Water Rate Increases .... John H. Murdoch Jr.
Panel Discussion—Water Main Extension Policies of New Jersey .. *Led by* Richard E. Bonyun
Panel .... J. Arthur Carr, Calvin F. Ellis, C. D. Moon, John J. Reager and E. D. Sheehan
Mechanization of Water Works Operations, Laying Mains, Services, etc. .... R. B. Freeman, J. G. Carns and W. D. Monie
Round Table Discussion .... *Led by* E. Vernon Smith
Water Main and Service Problems
Thawing Frozen Services
Installing Services
Connecting Pipes of Different Materials
Flushing Programs
Cathodic Protection

North Carolina Section—November 8–10, 1948

Address of Welcome .... *Mayor* Clarence E. Morgan
Gravity Water Supplies of Western North Carolina .... Thad C. Burnett
High, Low, Jick, Jack, Joker and the Game .... D. M. Williams
Observation on Reconditioning of a 24-in. Pipeline by the Pittsburgh Eric Process .... George S. Rawlins
Round Table Discussion of Water Works .... *Led by* T. E. Witty
Recent Manganese Trouble in Greensboro's Water Supply .... W. M. Lybrook
Corrosion .... R. Henry Teeter
Revamping of Mixing Chambers .... Hoyt G. Bailey
Water Rates and Fire Protection Beyond City Limits .... J. L. Perkins
Water Main Extensions .... Kent Matthewson
Barnacles, Mud Rust and Muck in a Municipal Water Supply .... M. O. Butler
Reports and Their Use in Water Plant Operation .... R. W. Haywood Jr.
Snow and Rain Production .... Bernard Vonnegutt
Round Table Discussion of Sewage Works .... *Led by* Emil T. Chanlett
Panel .... Earle Axe, Robert S. Phillips, George S. Rawlins and D. York Brannock
The Use of Activated Sludge Treatment in Small Plants .... F. L. Bunker
Operation Details of Sewage Treatment .... W. H. Wisely
Relation of Plant Changes to River Conditions .... F. V. Doutt

Florida Section—November 18–20, 1948

Address of Welcome .... *Mayor* Carl R. Gray
Response .... W. A. Glass
Application and Maintenance of Electrical Equipment .... W. J. Seibert
Method of Checking Efficiency of Water Pumps While in Service ...... Newton C. Ebaugh
Improvements to Hialeah Treatment Plant and Automatic Control of Carbon Dioxide Gas to Maintain Uniform pH .... C. R. Henry
The Functions of the Cast Iron Pipe Research Association .... Thomas F. Wolfe
Panel Discussion—Deterioration of Plant and Distribution System and Preventive Maintenance .... Stanley Sweeney and L. L. Garrett
Financing Extensions and Improvements .... Ross E. Windom
Panel Discussion—Disinfection of Mains .... Charles H. Helwick, W. H. Young, Ormond Beach and Benjamin F. Borden Jr.
Meter Shop Practice—Testing and Maintenance of Meters .... W. T. Rimile

Cuban Section—December 2–4, 1948

Address of Welcome.. *Mayor* Nicolas Castellanos
Aspects of Havana City Water Works................Abel Fernandez and Ernesto Trelles
Treatment of Sewer Liquid—Biofiltration Process......................J. M. Valdés Roig
The University of Havana and Its Relation to the Various Water Supplies...............
Luis Alberto Núñez
Electric Conductivity in Water Analysis.........................Leandro de Goicoechea
Reduction of Nitrates to Nitrites in Drinking Water.......................Julio C. Pita
Matanzas Water Works—History and Present Improvement Program......T. M. Victory

Southeastern Section—December 6–8, 1948

Recent Advances in Water Treatment.......................................A. P. Black
Impounding Available Water to Supplement Existing Supplies..........Laurence G. Leach
Modern Methods of Adjusting Rates...W. R. Wise
Discussion...T. E. P. Woodward
Financing Water Services Beyond City Limits.............................J. L. Hawkins
Discussion...Henry M. Mathews
Financing Water System Development...............................Frederick L. Bird
Discussion...George H. Sparks
Distribution System Symposium:
Water Waste Surveys...Homer E. Beckwith
Discussion..Thomas C. Earl
Water Use by Air-Conditioning Equipment...........................Lewis L. Barnes
Discussion..Frank W. Chapman
National Board of Fire Underwriters' Evaluation of a Water Supply System...........
Harvey N. Pye
Discussion.......................................Francis B. McDowell Jr.
Improved Methods of Coagulation..................................Charles H. Starling
Discussion..H. Grady Wilds
Mechanics of Distribution System Sampling..............................A. T. Storey
Discussion..Alan M. Johnstone
Stream Pollution Control Is Here.....................................Carl E. Schwob
Discussion...............................Gilbert R. Frith and T. A. Kolb

Section Membership at Time of, and Total Attendance at, Section Meetings—1944–1948

SECTION	1944		1945		1946		1947		1948	
	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance
Alabama-Mississippi	*	*	*	*	*	*	52	87	137	116
Arizona‖	*	*	*	*	*	*	26	134	41	159
California	638	926	663	503	684	857	726	§	770	1133
Canadian	323	555	353	800	383	600	404	730	459	732
Cuban	34	†	38	‡	36	26	36	116	36	†
Florida	138	157	134	120	149	142	165	116	190	103
Four States	324	325	336	202	343	172	350	180	343	191**
Illinois	293	126	330	219	353	‡	362	318	402	321
Indiana	202	221	206	386	203	226	206	224	201	242
Iowa	*	*	*	*	67	106	93	115	95	157
Kansas	*	*	*	*	55	107	93	132	110	118
Kentucky-Tennessee	127	‡	129	†	131	98	132	133	138	206
Michigan	135	205	150	152	181	230	199	222	232	248
Minnesota	102	202	120	146	120	179	161	206	172	322
Missouri	*	*	*	*	154	†	149	195	154	76
Missouri Valley	228		294	166	254	§	¶	¶	¶	¶
Montana	53	82	57	43	59	78	61	69	63	108
Nebraska	*	*	*	*	*	*	35	†	41	†
New England	154	‡	161	‡	170	57	172	‡	172	‡
New Jersey‖	266	119	291	91	305	250	309	217	320	208
New York‖	510	†	526	332	575	126	627	230	644	200
North Carolina	155	‡	156	272	162	237	169	212	174	238
Ohio	255	261	267	†	332	†	336	251	364	258
Pacific Northwest	222	242	228	‡	267	234	267	234	264	260
Rocky Mountain	91	128	94	90	103	84	117	92	135	74
Southeastern	217	274	231	‡	238	179	151	136	149	†
Southwest	328	573	359	211	434	430	557	428	558	545
Virginia	113	160	122	175	125	219	146	201	154	224
West Virginia	75	117	76	†	80	131	82	120	88	172
Western Pennsylvania	147	‡	152	155	159	115	157	132	159	191**
Wisconsin	125	‡	129	255	133	272	138	302	146	239

* Section not then organized.
† No record of attendance.
‡ No regular meeting scheduled. Membership given as of dates of conferences for 1944, 1946–1948, and as of June 30, 1945.
§ Regular meeting cancelled. Business meeting held at annual conference.
‖ Only one meeting recorded here.
¶ Section discontinued.
** Joint meeting, to form Chesapeake and Pennsylvania Sections.

Section Meetings—1944–1948

Section	*1944*	*1945*	*1946*	*1947*	*1948*	*Meeting Place—1948*
Alabama-Mississippi	—	—	—	May 23–24	Oct. 13–15	Montgomery, Ala.
Arizona	—	—	—	Oct. 9–11	Apr. 2–4	Globe, Ariz.
					Oct. 15–17	Phoenix, Ariz.
California	Oct. 24–26	Oct. 23–25*	Oct. 22–25	—	Oct. 27–29	Riverside, Calif.
Canadian	Apr. 19–21	Mar. 19–21	Apr. 8–10	Apr. 14–16	Apr. 12–14	Niagara Falls, Can.
Cuban	—	—	Nov. 22–24	Nov. 20–22	Dec. 2–4	Havana, Cuba
Florida	Nov. 16–18	Nov. 15–17	Nov. 22–24	Nov. 20–22	Nov. 18–20	Panama City, Fla.
Four States	Nov. 8–10	Dec. 13–15	Sept. 26–28	Nov. 19–21	Oct. 20–22	Philadelphia, Pa.
Illinois	Apr. 11–13	Oct. 30–31	—	Apr. 17–18	Apr. 15–16	Chicago, Ill.
Indiana	Apr. 13–14	June 12–22*	Apr. 2–3	May 7–9	Apr. 21–23	Lafayette, Ind.
Iowa	—	—	Nov. 4–5	Oct. 9–11	Oct. 5–6	Fort Dodge, Iowa
Kansas	—	—	Mar. 7–8	Mar. 13–14	Mar. 11–12	Wichita, Kan.
Kentucky-Tennessee	—	June 4–5	Oct. 28–30	Sept. 22–24	Aug. 23–25	Chattanooga, Tenn.
Michigan	Apr. 26–28	Sept. 19–20	Sept. 18–20	Sept. 18–20	Sept. 22–24	Flint, Mich.
Minnesota	Mar. 16–17	Sept. 11–18*	Mar. 14–15	Mar. 13–14	Sept. 1–2	Winnipeg, Man.
Missouri	—	—	Oct. 21–22	Oct. 27–28	Oct. 24–26	Jefferson City, Mo.
Missouri Valley	—	Oct. 29–30	—	—	—	
Montana	May 5–6	Apr. 13–14	Apr. 12–13	Apr. 25–26	Apr. 9–10	Livingston, Mont.
Nebraska	—	—	—	Apr. 11–12	Apr. 22–23	Lincoln, Neb.
New England	—	—	Oct. 17	—	—	
New Jersey	Feb. 10	Jan. 29	Mar. 1	Feb. 19	—	
	May 11	July 25	—	June 19	—	
	Nov. 2–4	Nov. 8–10	Nov. 7–9	Nov. 6–8	Nov. 4–7	Atlantic City, N.J.
New York	Apr. 27–28	Jan. 17	Mar. 28–29	Apr. 10–11	Apr. 1–2	Syracuse, N.Y.
	—	May 22–25*	Oct. 3–4	Sept. 4–5	Sept. 14–17	New York, N.Y.
North Carolina	—	Nov. 5–7	Nov. 18–20	Nov. 10–12	Nov. 8–10	Asheville, N.C.
Ohio	May 18–19	Oct. 23–26*	Oct. 10–12	Sept. 30–Oct. 2	Oct. 7–8	Mansfield, Ohio
Pacific Northwest	May 12–13	—	May 23–25	May 15–17	May 13–15	Boise, Idaho
Rocky Mountain	Sept. 20–22	Sept. 21	Sept. 12–13	Sept. 25–26	Sept. 15–17	Cheyenne, Wyo.
Southeastern	May 8–10	—	Sept. 9–11	Nov. 3–5	Dec. 6–8	Augusta, Ga.
Southwest	Oct. 17–19	Oct. 16–17	Oct. 14–17	Oct. 12–15	Oct. 11–13	Galveston, Tex.
Virginia	Nov. 14–15	Nov. 8–9	Nov. 14–15	Nov. 17–18	Oct. 25–26	Richmond, Va.
West Virginia	Oct. 26–27	Nov. 15–16	Oct. 17–18	Oct. 2–3	Sept. 30–Oct. 1	Clarksburg, W.Va.
Western Pennsylvania	—	Sept. 14	Sept. 12–13	June 12–13	Oct. 20–22	Philadelphia, Pa.
Wisconsin	—	Nov. 13–15	Nov. 15–17	Oct. 23–25	Oct. 28–29	La Crosse, Wis.

* Regional meetings.

Subject Index

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Binding of the Year's Journals

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Author Index

Abstract Index

All subjects and page numbers in boldface type are the first pages of topic sections or of a number of abstracts on the particular subject.

Authors of Abstracted Articles

JOURNAL

AMERICAN WATER WORKS ASSOCIATION

VOL. 40, NO. 12
TWO PARTS

DECEMBER 1948
PART ONE